# Summary

The Wimmera Catchment Management Authority (WCMA) region in western Victoria contains the Wimmera River catchment and part of the Millicent Coast Basin to the South Australian border. The region forms the south-west part of the Murray Darling Basin and covers 23 500 square kilometres or 10.3% of Victoria’s total area. It extends from the Grampians Ranges in the south to Lake Albacutya in the north, and from the South Australian border in the west to Navarre in the East. The Wimmera River (largest terminal river in Victoria) is the major waterway in the region and is the focus of many social, cultural and environmental values.

Most of the Wimmera has been cleared for broadscale agriculture with cropping the main enterprise making agricultural land a key asset. Management of the land and soil affects a wide variety of natural resource management issues. The prominent regional industries of agriculture and tourism are dependent on the conservation and sustainable use of the natural assets such as the soil.

Soil is a key regional asset and provides the basis for agricultural production, acts as a buffer against environmental pollution, is a repository for wastes, and forms the hydrological interface between rainfall, runoff, recharge, groundwater storage and streamflow. Soil is therefore pivotal and fundamental in the provision of agricultural production and ecosystem services, both of which can be compromised if land is inappropriately managed. Land use and land management choices rely on maintaining the versatility of soil. Protection, maintenance and enhancement of soil quality are the requirements for sound management and necessitate a thorough knowledge of soil differences. Land resource assessment provides understanding of the range of soils and their relationships in the landscape and is an essential tool for any land use activity, from agriculture to waste disposal.

This 1:100 000 scale land resource assessment (LRA) project for the WCMA region was commissioned to develop and provide consistent land resource information across the region. This study provides the science and improves the platform of knowledge from which policy and strategies (e.g. Wimmera Regional Catchment Strategy, Wimmera Soil Health Strategy) can be developed. Future emphasis on research into sustainable farming systems, catchment condition target setting and program development at a regional scale is now required.

The primary objectives of the LRA project were:

- To undertake an inventory of soils and landforms to establish a continuous spatial dataset for the WCMA region. As the first consolidated dataset of this type for the region, the information from the soil point data and the spatial mapping will become key datasets for input into catchment and natural resource modelling applications.
- To provide land degradation hazard susceptibility information to identify potential on-site and off-site impacts to underpin decision making regarding current and future land use.
- To provide information that will enable future land capability assessment for the catchment; designed to attract investors to the region and to ensure that investment takes place in areas where there is low economic and environmental risk.
- To increase the efficiency and effectiveness of natural resource utilisation in the region.
- To provide specialist land resource assessment (LRA) training to Catchment and Agricultural Services (CAS) staff and other stakeholders.

The data and information derived from this project can be used for spatial analysis of future landscapes (possibly for condition, classification or resource definition), as well as identifying land management issues including land hazards, land capability, soil decline, natural assets (e.g. soil and

soil ecosystems). This information, in combination with modelling to identify areas of risk, can support priority setting for initiatives, programs or policies to implement and manage land use change.

This report provides a consistent soil-landform dataset that will assist future opportunities to develop sustainable primary production (farming systems) and processing enterprises, as well as maintain ecosystem services within this region.

To enable stakeholders and the community to use the information the data has been made available on CD-ROM that is a stand-alone product and does not require any extra software to open and use it. This allows easy access to the information via Adobe Acrobat Reader and enables the user to print maps, land unit information and the text of the report.

In presenting this report, the authors would like to emphasise three points:

- That the report and information products generated by this project be available at regional locations to enable stakeholder and community access.
- That assessment of future land use change should be carried out with respect to hydrological processes such as salinity recharge and discharge, groundwater and surface water availability for irrigation, and surface water quality impacts. Such assessment would utilise the soil-landform mapping as a basis for scenario modelling.
- That stakeholders and the community be directed to the Victorian Resources Online website (www.dpi.vic.gov.au/vro) for additional information on land and water resources in the WCMA region.

The nominal scale recommended for use of this spatial dataset and soil-landform inventory is 1:100 000. This is appropriate for broadscale assessment of land capability and regional planning. Local government may find the data strategically useful, but finer resolution mapping (particularly of map unit boundaries) is recommended for reconciliation with local government planning scale (1:40 000). The soil inventory (soil descriptions and associated chemical data) may be used to inform future mapping at finer scale (farm planning for example). This report draws substantially on a suite of soil surveys that have been conducted in the region over the past 60 years that have generated numerous maps and detailed soil descriptions, many of which are included in this report.

Map units and boundaries published in the earlier surveys have been modified to reflect the new geomorphological framework for Victoria. This framework is hierarchical and is based on a top-down approach to landscape analysis and includes at the highest level the four geomorphic divisions: the Western Uplands, Northern Riverine Plains, North West Dunefields and Plains, and Western Plains. Progressive subdivisions of these units have been made in this study, with the resultant 1:100 000 soil-landform map units forming a fourth tier in the hierarchy.

The region has been divided into over 100 soil-landform units, and for each of these the principal land elements have also been described and presented in a series of tables. In spite of the variety and complexity of the plains and uplands, there are many features of the region’s soils that are held in common, regardless of the parent material from which they have been developed (otherwise known as Wimmera Soil Groups).

Interpretation of the regional soil and land qualities that affect susceptibility to different forms of land degradation has been used to generate maps of land degradation hazard. These maps do not represent current land condition or actual land degradation.

The inventory has enabled production of inherent land degradation susceptibility maps for the Wimmera that include:

- gully and tunnel erosion
- sheet and rill erosion
- wind erosion
- soil structure decline (compaction)
- soil sodicity (topsoil and subsoil)
- soil pH (topsoil and subsoil).

The land degradation analysis has indicated that there are substantial areas at risk from land and water degradation in the WCMA region. The following tables provide a breakdown of the area (given in hectares and as a percentage) into different risk categories for the above land and water degradation themes, soil pH and soil sodcity.

| Hazard | High and Very High | | Moderate | | Low and Very Low | |
|---|---|---|---|---|---|---|
| | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| Gully and tunnel erosion | 132443 | 5.7 | 1076613 | 46.5 | 1107970 | 47.8 |
| Sheet and rill erosion | 63401 | 2.7 | 985185 | 42.5 | 1268422 | 54.8 |
| Wind erosion | 1001457 | 43.2 | 1098882 | 47.4 | 216668 | 9.4 |
| Soil structure decline (compaction) | 436212 | 18.8 | 770353 | 33.2 | 1110443 | 48.0 |

| Sodicity | Very strongly sodic (ESP > 25 | | Strongly sodic (ESP 15–25) | | Sodic (ESP 6–15) | | Non sodic | |
|---|---|---|---|---|---|---|---|---|
| | (ha) | (%) | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| Topsoil | 117686 | 5.1 | 0 | 0 | 576971 | 24.9 | 1622371 | 70.0 |
| Subsoil | 846019 | 36.5 | 477772 | 20.6 | 660388 | 28.5 | 332830 | 14.4 |

| Soil pH | Acid (pH < 5.5) | | Neutral (pH 5.5–8.0) | | Alkaline (pH >8.0) | |
|---|---|---|---|---|---|---|
| | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| Topsoil | 89750 | 3.9 | 1551669 | 67.0 | 675590 | 29.1 |
| Subsoil | 1994 | 0.1 | 987044 | 42.6 | 1327971 | 57.3 |

In the WCMA region it is apparent that particular soil-landform units are naturally prone to land and water degradation and the following generalisations can be made:

- The hills and mountains (Grampians, Pyrenees and Langi Ghiran range) in the Western Uplands along with colluvial granite and sedimentary slopes are extremely prone to tunnel and gully erosion, and sheet and rill erosion especially where cleared.
- The Little and Big deserts, and the sandy dunes and ridge crests in the north of the region are highly susceptible to wind erosion.

- Landscapes thought most vulnerable to soil structure decline include the sedimentary slopes and plains of the Western Uplands with hard setting soil surfaces, massive cracking clay soils and sodic texture contrast soils of the North West Dunefields and Plains.
- Sodic soils are common in the north and west of the region along with hardsetting alluvial plains associated with prior streams and modern stream channels in the east of the catchment.
- Higher rainfall (> 500 mm) areas typically have acidic soil surfaces that trend towards neutral in the subsoil including the plains south of the Little Desert and Western Uplands landscapes.
- Further north (e.g. Jeparit, Peppers Plains) topsoil pH values are often alkaline with some surface values near 10. Subsoils here are still alkaline but may become neutral at depth (>1.5 m).

# Preface

The purpose of this study has been to provide essential soil and land information that provides a strong scientific basis to guide land management and related policies across the WCMA region of Victoria. New technology and the application of improved farming systems are the key drivers for land use change and sustainable land management, and this process requires more detailed soil information. The 1:100 000 scale soil-landform survey for this region complements a similar study for the neighbouring Glenelg-Hopkins CMA (Baxter & Robinson 2001) and completes the work at this scale for western Victoria.

Although a number of historical land resource surveys have been undertaken within this region, they cover smaller areas, or are at coarser scales with less detail. The Wimmera Land Resource Assessment (WLRA) project undertaken by the Department of Primary Industries (DPI)-Primary Industries Research Victoria (PIRVic) now provides a comprehensive, consistent soil-landform survey for this region.

The data gathered during this project has been used to develop land hazard degradation susceptibility maps. However, the availability of soil-landform data and soil point data allows for more specific and detailed applications in future that include catchment modelling, scenario modelling and possibly future redesign of landscapes for sustainability. It will enable a clear understanding of the potential to develop land for various agricultural enterprises and to identify limitations linked to the natural resource base. The ability to access detailed soil point information and soil-landform units will benefit many modelling applications currently used to assess land resource management and water quality aspects such as Land Use Impact Model (LUIM), Soil and Water Assessment Tool (SWAT) and the Catchment Assessment Tool (CAT). Soil point information has been collected and is stored according to national protocols in the Victorian Statewide Soil Site Database (VSSD). This allows access to soil point information for incorporation in spatial models.

At the map scale of this project (1:100 000), soil-landform units are not homogeneous. Often a co-dominant and minor soil type have been described as part of this process. Importantly it should be noted that, at this mapping scale, soil attributes (for example soil depth, soil structure, size and abundance of coarse fragments, sodicity, pH) are expected to vary within map units.

As the variability of soil attributes within a map unit is difficult to predict, it is important to note that the representative soils should be used as a guide only. Site specific mapping and soil analysis is essential prior to establishment of any new development or enterprise.

Map unit and detailed soil profile information can be accessed in either Internet Explorer or Netscape Navigator from Adobe Acrobat files included on this CD-ROM via the index htm file.

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- Wimmera Catchment Management Authority
- Department of Primary Industries–Primary Industries Research Victoria
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# List of abbreviations

| | |
|---|---|
| API | Aerial Photograph Interpretation |
| ASC | Australian Soil Classification (Isbell 1996) |
| AWC | available water capacity of soils |
| CAS | Catchment and Agricultural Services, DPI (formerly NRE) |
| CAT | Catchment Assessment Tool |
| CAW | Catchment and Water Division, DSE (formerly NRE) |
| CLPR | Centre for Land Protection Research |
| CMA | Catchment Management Authority |
| DEM | digital elevation model |
| DPI | Department of Primary Industries (formerly NRE) |
| DSE | Department of Sustainability and Environment (formerly NRE) |
| ESP | exchangeable sodium percentage |
| EVC | Ecological Vegetation Communities |
| FK | Factual Key (Northcote 1979) |
| GIS | geographic information systems |
| ka | thousand years ago |
| LRA | land resource assessment |
| LUIM | Land Use Impact Model |
| mASL | metres above sea level |
| Ma | million years ago |
| NRE | Department of Natural Resources and Environment |
| PIRVic | Primary Industries Research Victoria (R&D division of DPI) |
| SCL | State Chemistry Laboratories, Werribee |
| SWAT | Soil and Water Assessment Tool |
| VRO | Victorian Resources Online |
| WCMA | Wimmera Catchment Management Authority |
| WLRA | Wimmera Land Resource Assessment |

# A land resource assessment of the Wimmera region

*Nathan Robinson, David Rees, Keith Reynard, Mark Imhof, Grant Boyle, John Martin, Jim Rowan, Colin Smith, Kathryn Sheffield, Shane Giles*

## 1 Introduction

Soil provides the basis for our agricultural production, acts as a buffer against environmental pollution, is a repository for wastes, and forms the hydrological interface between rainfall, runoff, recharge, groundwater storage and streamflow. Soil is therefore pivotal in the provision of fundamental ecosystem services. Land use and land management choices rely on this versatility of soil but can also compromise these services if land management is applied inappropriately. Protection, maintenance and enhancement of soil quality are the foundations for sound environmental management and necessitate the knowledge of soil differences. Land resource assessment, which provides the understanding of the variety of soils and their relationships in the landscape, is an essential tool for any land use activity, from agriculture to waste disposal.

The WimmeraCatchment Management Authority (WCMA) region encompasses almost 13 350 km$^2$ of western Victoria. This includes the Wimmera plains, the Western Uplands (Central Highlands) and the Western Plains, as well as a suite of rivers and creeks that travel northwards as terminal systems (Wimmera River, Yarriambiack Creek and Dunnmunkle Creek). The region is a traditional agricultural region that has been experiencing increases in agricultural intensification, especially dryland cropping systems (WCMA 2003), grazing and irrigated horticulture systems, and other forms of agricultural enterprise (WCMA 2003). While intensification in agriculture is expected, a growth in tourism and recreation is a force to be considered in future natural resource allocation, consumption and sustainability. Public land is mainly confined to the Grampians Ranges and Central Highlands where nature conservation and recreation are the main land uses, whilst the freehold land on the plains is used predominantly for dryland cropping, sheep, beef and dairy enterprises.

In 2002 work commenced on an inventory of soils and landscapes across public and freehold land within the region. Work undertaken by Primary Industries Research Victoria (PIRVic) includes a major land resource assessment (LRA) project in the WCMA region to provide detailed information to underpin any future land capability or land degradation assessment.

The work program has allowed for the development of a 1:100 000 scale land resource dataset. The land resource data in this project is a soil-landform unit dataset based upon an integration of landform, geological and soil information in the identification of unique land units. Land degradation susceptibility mapping has also been developed using expert and regional knowledge to assess soil-landform units for their inherent vulnerability to degradation processes.

The data and information derived from this work program can be used for spatial analysis of future landscapes (possibly for condition, classification or resource definition), as well as identifying land management issues including land hazards, land capability, soil decline, natural assets (e.g. soil and soil ecosystems). This information, in combination with modelling to identify areas of risk, can support priority setting for initiatives, programs or policies to manage land use change.

This report provides a consistent soil-landform dataset that will assist future opportunities to develop sustainable primary production (farming systems) and processing enterprises, as well as maintain ecosystem services within this region.

Data collected and generated as a result of this project enables all stakeholders to access key land resource information, and will help to discriminate areas suitable for various land uses and land management practices. The ability to access detailed soil point information, as well as soil and land unit spatial data will benefit many modelling applications that are currently used to assess land resource management and water quality aspects. The project will ultimately be useful in encouraging the development of a common and coordinated approach to the selection of sustainable land use options and land management practices into the future from an integrated policy and improved farming systems perspective. This inventory provides base soil and land information by which identification of threats and opportunities can be made (Figure 1). These interpreted products along with future research, are key ingredients to support policy and planning requirements of government and stakeholders.

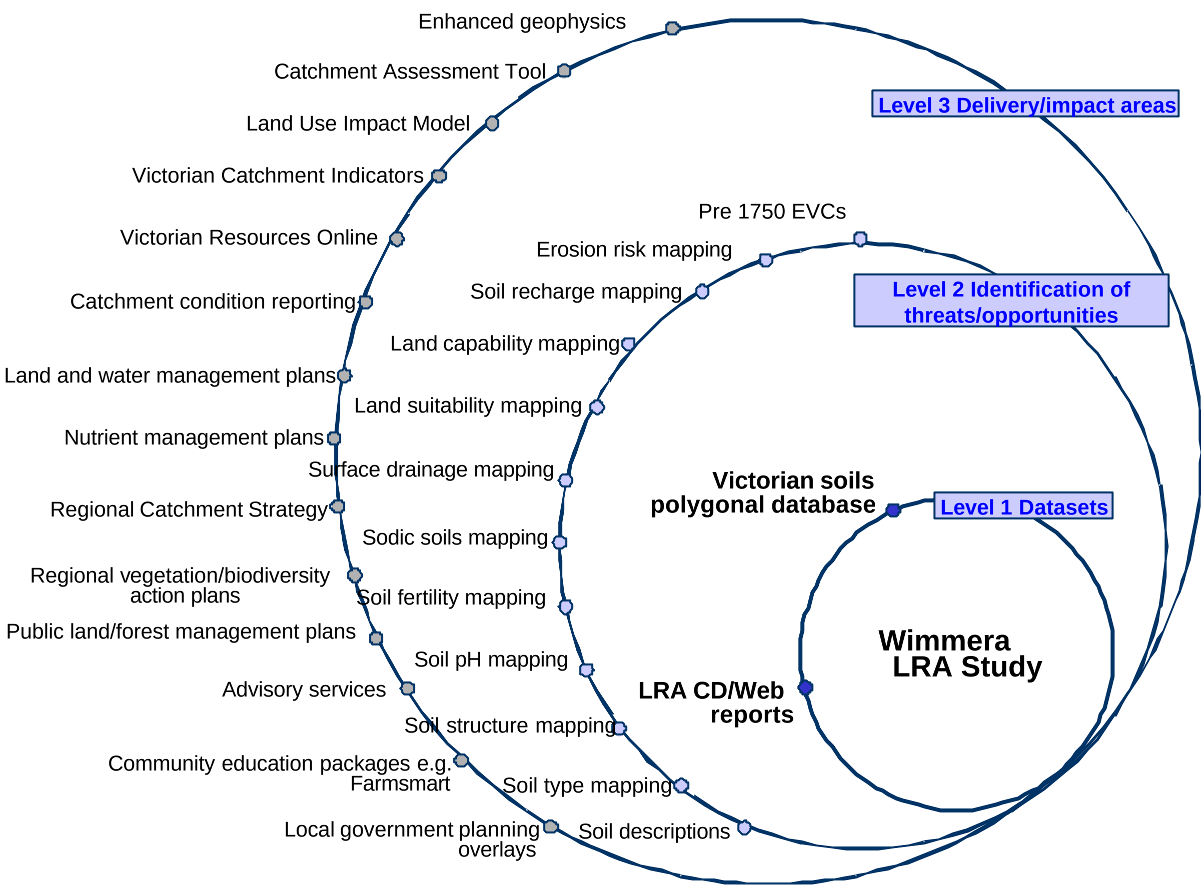



Figure 1 Relationship between WLRA, and future research, policy and planning requirements

## 1.1 Objectives

The primary objectives of the project were:

- To undertake an inventory of soils and landforms to establish a continuous spatial dataset for the WCMA region. As the first consolidated dataset of this type for the region, the information from the soil point data and the spatial mapping will become key datasets for input into catchment and natural resource modelling applications.

- To provide land degradation hazard susceptibility information to identify potential on-site and off-site impacts to underpin decision making regarding current and future land use.
- To provide information that will enable future land capability assessment for the catchment, designed to attract investors to the region and to ensure that investment takes place in areas where there is low economic and environmental risk.
- To increase the efficiency and effectiveness of natural resource utilisation in the region.
- To provide specialist land resource assessment (LRA) training to DPI Catchment and Agricultural Services (CAS) staff and other stakeholders.

## 1.2 Location of the study area

The WCMA region in western Victoria contains the Wimmera River catchment and part of the Millicent Coast Basin to the South Australian border. The region forms the south-west part of the Murray Darling Basin and covers 23 500 square kilometres or 10.3% of Victoria's total area. It extends from the Grampians Ranges in the south to Lake Albacutya in the north, and from the South Australian border in the west to Navarre in the East. The Wimmera River (largest terminal river in Victoria) is the major waterway in the region and is the focus of many social, cultural and environmental values. (Figure 2).

## 1.3 Links to other projects

This project is linked to a number of key projects including Regional Data Net, Victorian Catchment Indicators and Victorian Resources Online (http://www.dpi.vic.gov.au/vro). Information collated and derived from this report builds upon concepts and background data derived in the report *Land and soil survey in the Wimmera region: Data inventory and evaluation of methodologies for soil mapping*:

- Part 1: A review of methods for surveying soils at different map scales (Robinson et al. 2003a)

  This is a desktop investigation of existing yield information and its application in land management, toposequences and the role of soil survey in land assessment.

- Part 2: Evaluating a methodology for strategic soil-landform mapping in the Wimmera (Robinson et al. 2003b)

  This study evaluates and documents procedures used in integrating Enhanced Resource Assessment (ERA) techniques in land assessment for sustainability and productivity.

- Part 3: Data inventory (Robinson et al. 2003c)

  This inventory assembles existing information to provide strategic outcomes and recommendations as a basis for future land resource assessment in the Wimmera.

## 1.4 Background

This study has concentrated on a comprehensive revision of soil-landform mapping and associated site descriptions. It is acknowledged that there are a number of associated datasets that contribute towards the framework for the study (such as the geomorphology, geology and climate) or complement the study at a similar scale (such as vegetation and land use).

Climatic and geological data have been sourced from geospatial datasets, many of which can be accessed electronically via Victorian Resources Online (VRO) or from relevant sources (DPI Minerals and Petroleum, Bureau of Meteorology). The information on the geomorphology provided in this report constitutes a new approach to soil-landform mapping in Victoria. This approach provides context for analysis of landscapes at a range of scales and degrees of complexity. The geomorphology provides the main framework in this study for the soil-landform units (approximates to detailed landsystems without some of the ecological connotations). This enables the description at the soil-landform level (1:100 000 scale) to be relatively scale free as many of the contextual issues are dealt with by the geomorphology at a number of smaller (broader) scales (or tiers). Links between the geomorphology and soil-landform are further discussed in the 'Geomorphology' section of this report.

Vegetation, biodiversity and land use information used in this report is based on existing data such as the Ecological Vegetation Community (EVC) mapping. The VRO website along with the Biodiversity Interactive Map (http://nremap-sc.nre.vic.gov.au/MapShare.v2/imf.jsp?site=bnr-v1) provides a portal to these datasets and updates on progress made in vegetation mapping across the catchment.

This report's intended usage is predominantly as a regional overview and should only be used as such. Users include the wider community, however the primary users are expected to include local government and regional extension staff (DPI and WCMA), with usage expected at a higher level for statewide applications (CAT, LUIM, carbon sequestration modelling, etc.).

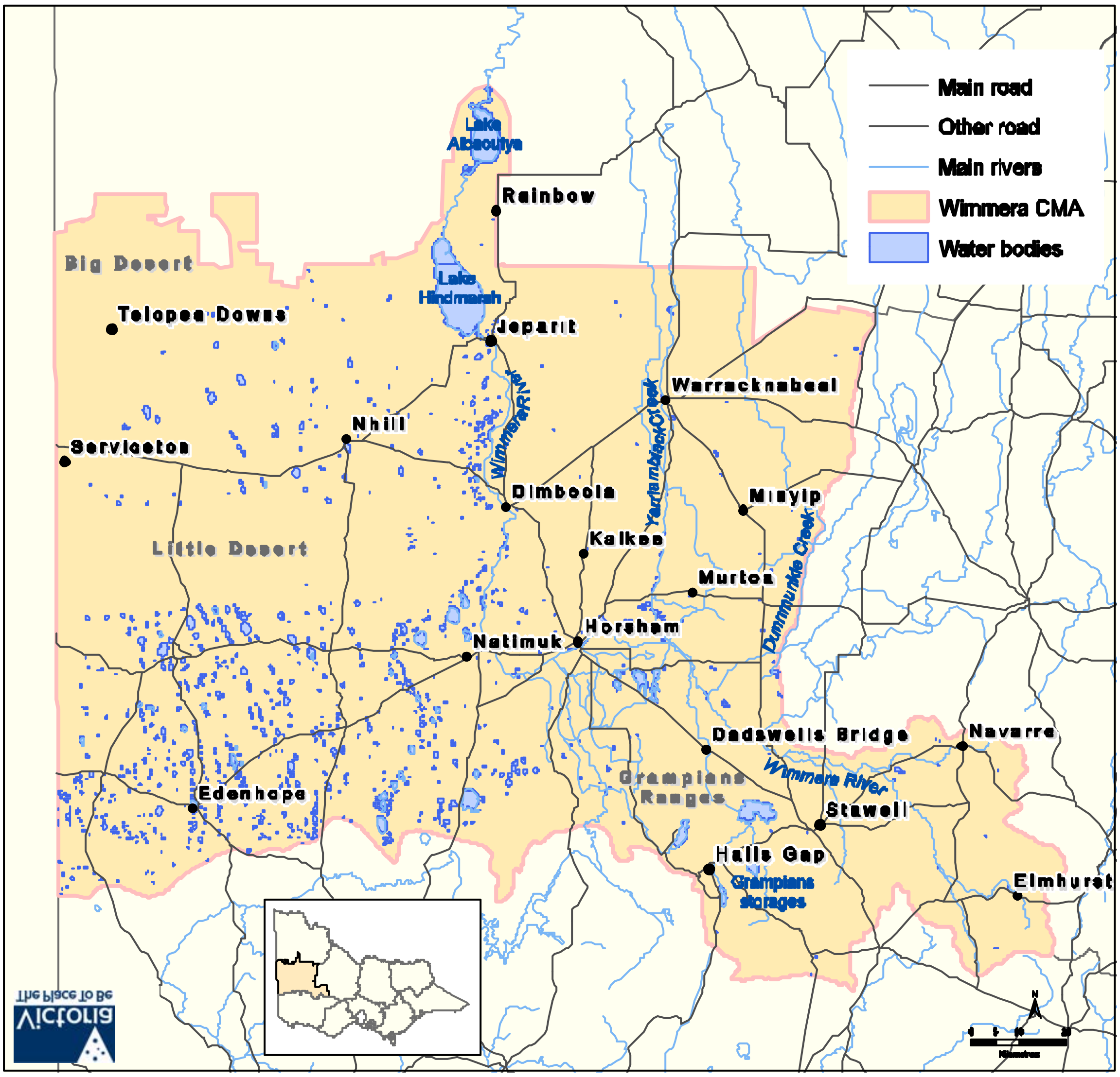



Figure 2 WCMA region and its major rivers

# 2 Geomorphology of the Wimmera

*John Martin, Jim Rowan, Bernie Joyce, David Rees, Nathan Robinson with acknowledgements to the Victorian Geomorphological Reference Group*

## 2.1 Landscape evolution of the Wimmera region

Western Victorian landscapes represent examples of the oldest preserved valleys and terrane in Victoria. Processes today including landslides, saline groundwater discharge, earthquakes and anthropic intervention/manipulation exasperate, and are manifestations of, landscape evolution processes. The WCMA region has formed through landscape-building episodes for over 500 million years (Ma) in a variety of environments from the fluvial non marine environments through to deep marine settings and explosive volcanic events. The following is a culmination of landscape and geological processes (including major lithological units) and have been summarised into five episodes with relevance to today's landscapes.

**Episode 1: Palaeozoic basement and rock evolution**

***Structural and tectonic evolution***

The Victorian crust or lithosphere has been designated into 10 structural zones, with the most western zones (Glenelg, Grampians-Stavely and Stawell) prominent in the WCMA region. The Glenelg River Metamorphic Complex, Rocklands Volcanics, early and late syn compressional intrusions and Bacchus Marsh Formation that lie on the south-western catchment divide of the Glenelg Zone will not be discussed but further information can be sourced from Morand et al. (2003).

As part of the Palaeozoic Tasman Fold Belt, or Tasman Orogenic system, the WCMA region falls across a major structural division between belts of deformed rocks from the Delamerian Orogen (over 500 Ma) in the west of the catchment, and the Lachlan Orogen (Benambran-Tabberabberan Orogenic Periods) in the east.

The Delamerian Fold Belt (Delamerian Orogen) included the Glenelg Zone and Grampians-Stavely Zone. The later is not considered part of the Adelaide Geosyncline (VandenBerg et al. 2000) and consists of syn-orogenic Cambrian age calc-alkaline volcanics (Mount Stavely Volcanics) overlying Glenthompson Sandstone that were sourced from weathering Adelaide Geosyncline rocks (Cayley and Taylor 2001). Rocks were weakly deformed and metamorphosed including the Dimboola Igneous Complex (forearc-arc complex that resulted from the passive margin collision with the migrating Palaeo-Pacific crust or future Lachlan Fold Belt).

As part of the supercontinent Gondwana, the Lachlan Orogen saw development of sedimentary accretionary wedges that were pushed westerly onto the Australian craton. The sediments (sands, silts, and clays) were sourced from higher Delamerian Uplands into alluvial and marine systems that carried large loads to the sea floor. There they were often later deposited as a consequence of violent events as turbidite deposits at deeper bathometric levels on ancient sea floors (ancestral Melbourne trough of the Palaeo-Pacific crust).

During the Benambran Orogeny (455 Ma to 420 Ma), regional deformation of the Lachlan Fold Belt saw these rocks (sandstone, siltstone and claystone of the deep marine Cambro-Ordovician pile – St Arnaud and Castlemaine groups) initially gently folded with quartz veins parallel to bedding, later (at 445 Ma) increasingly folded into tighter sequences (chevron folds), then due to reaching strain limits resulted in further deformation and back thrusting of rocks onto the Delamerian basement. These sedimentary rocks were intermixed with deformed sea floor volcanics, slate belts (often gold bearing), granitic batholiths and plutons, volcanic complexes and regional metamorphic belts (Birch & VandenBerg 2003).

Basal decollment along the Marathon Fault in the late Silurian resulted in extensional listric thrust faulting and segmentation of the Grampians Group and underlying Palaeozoic basement rocks (Cayley & Taylor 2001). The sedimentary and underlying Palaeozoic rock stack remained at low angles from low angle fault ramps during the deformation. The Wartook Syncline is likely to have formed late in this time of deformation, with sandstones and thrust sheets exhibiting high strain deformation features (Cayley & Taylor 2001). The Grampians Ranges are likely to have existed as a large mountain range rising thousands of metres above neighbouring Cambrian rocks to the west and Palaeozoic basement to the east (Morand et al. 2003). This topography was strongly controlled as strike ridges with deep valleys and rapid erosion. Current day valleys assimilate prehistoric conditions with minor modifications (development of extensive valley floors through sediment and volcanic infill) making these extremely old landscapes and well preserved.

The Mount Stavely Volcanic Complex includes the Mount Stavely Belt and the Mount Dryden Belt that are both flanked by Glenthompson Sandstone (Cayley & Taylor 2001). The Mount Dryden Belt surficial exposures occur as a sequence of low hills and hills running from Jallukar to west of Lake Lonsdale. They comprise calc-alkaline andesitic and dacitic lavas, intrusives and fine grained volcaniclastics that reflect a late Delamerian Orogen post-collisional continental rift event (Crawford et al. 1996). The Glenthompson Sandstone comprises sandstone, greywacke and mudstone beds of turbidite formation and is largely overlain by more recent deposits in the Mount William Creek catchment. Magdala Volcanics found in the Magdala mine at Stawell and Moornambool Metamorphic Complex occurs as fault belts (north-westerly trend) that comprise basalt, volcanic derived sediments and chloritic schist.

### *Moornambool Metamorphic Complex*

This metamorphic complex is bound by the Moyston Fault to the west and the Coongee Fault on the east and includes upper green schist to amphibolite grade rocks that have been strongly deformed (Cayley & Taylor 2001). High grade rocks (amphibolite grade) found in the west are interpreted as basement rocks of the Lachlan Fold Belt with some rocks believed to be slithers of underlying Delamerian Fold Belt basement. Formations include the Deenicull Creek Schist (green schist, type site found south of the catchment boundary near Ararat); Rhymney schist (actinolite schist – upper green schist, type site is Rhymney Hill and Carrolls Cutting); Lexington Schist; Carrolls Amphibolite (amphibolite schist, type site is Carrolls cutting/Mount Ararat); Wonga Schist and the Good Morning Bill Schist (high grade amphibolite schist, type site is Mount Moornambool south of the catchment).

### *Cambro-Ordovician sediments*

The St Arnaud Group represents the turbidite sequence of Cambro-Ordovician sediments that are predominantly composed of unfossiliferous beds of sandstone and mudstone. Lying west of the Avoca Fault (Marlow & Bushell 1995) and overlying the Magdala Volcanics, the St Arnaud Group comprises three formations, namely the Warrak Formation, Beaufort Formation (comparable in age to the Warrak Formation) and the Pyrenees Formation (Cayley & McDonald 1995). The Warrak Formation, estimated to be 1.5-2.0 km thick, comprise quartz rich turbidites in which thick mudstone intervals occur and are derived from a deep marine setting with channel features derived from high density turbidity currents (Cayley & Taylor 2001). The Beaufort Formation is at least 1.0-1.5 km thick (Cayley & McDonald 1995) and is relatively rich in siltstone with beds of sandstone and shale common. The Pyrenees Formation, occurring as the Pyrenees Ranges, is estimated to be 2.5 km thick with higher sandstone content and greater bed thickness than the Beaufort Formation to the west.

### *Grampians sandstone*

The Grampians Group comprises shallow fluvio-deltaic marine deposits that are quartz rich and occur within the Grampians Ranges of the region. Red fine mudstones and contrasting coarse quartz sandstone rocks occur with basal conglomerate the lowest stratigraphic unit of the sequence. Outliers of the sequence include Mount Arapiles, MacKenzie River and Black Range in the WCMA region.

**Episode 2: Early Devonian igneous activity**

Granitic plutons of Early Devonian age (410–380 Ma) postdate the major structural events of the Tasman Orogeny and are represented by a belt of exposed south-west to north-east granite rocks within the upper catchment. These plutons and batholiths that have been derived from accumulation of magma in chambers 2 to 5 km below the ancient land surface of the Delamerian and Lachlan Fold Belts. The granites have intruded several of the major structural faults therefore placing age constraints on these structures. All intrusions are contact aureole in nature with aureoles ranging from 500 to 1500 m in width that encase the granitic pluton (Cayley & Taylor 2001). All granites postdate regional deformation events and are relatively undeformed while possessing textural features that indicate shallow intrusion level (Cayley & Taylor 2001).

Granites belonging to the Stawell Province of the Lachlan Fold Belt (Whitelaw Terrane) are recognised as I-type. These I-type granites are hornblende and magnetite bearing rocks that are metaluminous (White & Chappell 1988). The Stawell Province granites belong to three suites - Ararat, Mount Cole or Glenlogie.. Granites of the Ararat Suite include: Stawell Pluton (Stawell Granite, Two Eyed Creek Granodiorite, Bulgana Diorite, Cut Throat Diorite, Malakoff Granite, and White Rabbit Diorite); Ararat Pluton (Ararat Granodiorite, Curtis Diorite, and Merrymbuela Gabbro); MacKenzie River Granodiorite; and Navarre Granite. The Mount Cole Suite includes the Dunneworthy Granite; Eversley Granite; Ben Nevis Granite and Langi Ghiran Granite. The Glenlogie Suite includes the Glenlogie Granodiorite and Elmhurst Granite.

The Epacris Hills Granite occurs within the Mafeking Suite of granites in the Grampians Stavely Zone, therefore intruding the Delamerian crust and the overlying Grampians Group (Cayley & Taylor 1997).

Felsic dykes and sills associated with granitic plutons are widespread with quartz-feldspar porphyry, aplitic, granodioritic and rhyolitic dykes common. Most are undeformed. Mafic dykes within the Stawell gold mines are typically horizontal and transect all structures while postdating contact metamorphism. Lamprophyre dykes, nepheline basanite dykes and diorite dykes are most common with a diatreme associated with lamprophyre dykes of the Magdala mine.

**Episode 3: Late Palaeozoic – Mesozoic erosion and separation of Gondwana**

***Structural and tectonic evolution***

The mid-late Palaeozoic to Mesozoic saw a significant time span of little tectonic vulnerability and relative stability until the separation of Antarctica from Australia beginning in the Jurassic Period, around 170 Ma. The development of the Murray Basins eventuated with the downwarping in northern Victoria while the uplift formed the drainage divide of the Victoria Uplands. The separation of Gondwana also heralded the formation of the Otway Basin between Australia and Antarctica with the deposition of marine sediments within the normal/transfer fault system.

The Late Palaeozoic to Jurassic period was responsible for significant erosion of historic landsurfaces with stripping of several kilometres of rock, unroofing many on the granitic plutons and batholiths. Structural uplift, glaciation and denudation of landscapes were dominant processes (Hocking 2004) in erosion of prehistoric land surfaces and terrains. As a result of the extensive weathering and stripping of landscapes, Carboniferous and Permian sediments are sporadically preserved in troughs of the Murray Basin.

***Millewa Group and other various deposits***

Known as the Early Cretaceous sediments of the Murray Basin (Lawrence 1972), the sequence comprises clastic lithologies including sandstone to claystone and coal, deposited in a nonmarine to marginal marine environment (Lawrence 1972). These sediments overlie Permian-Cretaceous subcrop in the very north-west of Victoria (associated with the Wentworth Trough) with no outcrop in the WCMA region. The Permian-Carboniferous subcrop occurs along a north-west to south-east axis running through Horsham.

### *White Hills Gravel*

The rebounding of the continental margin from the Gondwana break-up resulted in extreme climatic events and weathering that saw rapid erosion of plateau-like remnants of the Mesozoic palaeosurface. High energy ecosystems including broad active river systems (Marlow & Bushell 1995) saw large regimes of silt, clay and sand removed from systems with coarse equivalents (e.g. gravel derived from quartz reef in Palaeozoic bedrock) deposited at current day elevations beneath that of a likely Mesozoic palaeosuface. Coarse angular to well rounded gravels are today found on hillslopes or cap low hills and rises of the current topography (Macumber 1991; Joyce 1992). Often underlying weathering is extreme with kaolinised bedrock under these silicified/ferruginised cappings that have often resulted in landscape inversion. These gravels have been mapped in the upper Wimmera catchment between elevations of 220 and 290 mASL (Hocking 1997). Little structural uplift in the region is believed to have occurred since this time due to the present distribution and tightly defined elevations from which these gravels occur in today's landscapes. While the White Hills Group (Willman & Wilkinson 1992) has been commonly used, the Great Western Group (Hughes, Carey and Kotsonis 1999) has been suggested for the WCMA region owing to the disconnected nature of deposits in Victoria.

### *Calivil Formation*

The Calivil Formation (Macumber 1972) comprises sediments sourced from the extensive weathering of the Palaeozoic basement and White Hills Group deposits as valley fill in the deepest extents of drainage systems of the Murray Basin and Victorian Highlands (Abele et al. 1988). Generally less than 10 m in thickness, they are poorly sorted sequences of fluvial sand and gravel within a matrix of kaolinitic clay as hosts to 'deep lead' palaeo placer gold deposits (Krokowski de Vickerod, Moore & Cayley 1997). They can be found in the Wimmera River and Mount William Creek valleys beneath current floodplain deposits where they pinch out in upper reaches of catchments.

### *Renmark Group*

While the Renmark Group sediments can be traced in areas into valleys of historic drainage networks, most of these sediments are confined to the Wimmera plains as the most extensive Palaeogene unit of the Murray Basin (Abele et al. 1988). Clay siltstones with various degrees of carbonate (Olney Formation) and medium to coarse grained sand with some carbonate (Warina Sand) underlie Calivil Formation deep lead deposits (Lawrence 1975).

### *Murray Group*

Marine carbonate sediments found in the east of the WCMA region (e.g. Millicent Coast Basin) include glauconite clays and limestones of the Ettrick Marl, bryozoal calcarenites, calacisilitites and calcirudites of the Duddo Limestone along with the dark grey glauconitic claystones and dolomitic siltstones of the Geera Clay (Birch 2003). The Geera Clay represents the palaeo transition between marine (Duddo Limestone/Ettrick Marl) and non marine (Calivil Formation) and provides an aquitard to westward migrating waters of non marine derived facies along with restricting upward gradients of water from the Renmark Group aquifers (Brown & Radke 1989)

## Episode 4: Miocene to Pliocene marine incursion and volcanism

### *Structural and tectonic evolution*

In the late Miocene to Pliocene time extensive flows of basalt migrated southwards towards the palaeo coastline of Victoria. These basaltic lavas filled many deep lead valleys and merged, resulting in rapid changes to steam and river courses.

During the late Miocene, the sea retreated from the Murray Basin (Cayley & Taylor 1997) resulting in the end of deposition within the Murray Group facies. As part of a warmer climate 5 to 6 Ma, an increase in sea levels resulted in a significant marine incursion across the Murray Basin that extended into drainage networks of remnant Palaeozoic terrane. This transgression was then followed by a fall in sea levels and retreat from the landscape leaving a series of former beach dunes as part of a greater sandsheet sequence. These shallow marine deposits are known as Parilla Sand and consist of fine to coarse grained quartz sand that have experienced later pedogenesis (known as the Karoonda Surface) caused by silicification and/or ferruginisation.

#### *Newer Volcanics*

The basalt flows of the Newer Volcanics in the region may have accumulated to thicknesses in excess of 150 m although large areas are covered by only 10 to 20 m (Cayley & Taylor 2001). The flow near Barton has buried underlying Cambrian basement rocks of the Grampians Stavely Zone. These deeply weathered basalts are the product of lobes of basalt ejected from the Willaura Hill eruption point.

### Episode 5: Pliocene to recent (today's landscape forming processes)

#### *Unconsolidated deposits (Qra, Qrt, Qrc)*

These reworkings of the Shepparton Formation comprise sand, silty clays and gravels (Krokowski de Vickerod, Moore & Cayley 1997) and are mainly found in drainage lines of the Wimmera River and Mount William Creek catchments. Known as the Coonambidgal Formation (Lawrence 1966 after Butler 1958), these reworked sediments are Late Pliocene to Holocene is age.

#### *Shepparton Formation*

This widespread fluvial system extends across much of the Murray Basin and extents of the WCMA region. Generally only a few to tens of metres thick, the unconsolidated sediments occur as larger alluvial floodplains with geomorphologically more recent active floodplains of the Coonambidgal Formation. Groundwater fluctuations combined with pedogenesis have modified the nature of these deposits. The unit conformably overlies the Calivil Formation and has stratigraphic linkages with the Parilla Sand and the ferruginisation process of the Karoonda Surface (Macumber 1983).

#### *Lake-lunette systems*

Swamps are scattered across the basalt plains near Barton where drainage is poorly developed in extremely weathered flows. Dune deposits on the eastern margin of Mount William Creek represent a mobile dunefield with sediments sourced from neighbouring colluvial gentle slopes of the Grampians plains. Here dunes may reach in excess of 10 m thick and can form veneers over basalt flow margins.

In the west of the region a series of chains of swamps and small lakes aligned in swales between stranded beach ridges of Parilla Sand are dominant. Lunettes are often associated with these ephemeral to permanent waterbodies and occur on the eastern shoreline to denote prevailing westerly winds. While there is no defined drainage network, these lakes and swamps receive water from localised runoff and through flow events, or from shallow groundwaters of varying salinity levels. Modern semi-arid conditions over the last 500 000 years has seen aeolian deposition of calcareous clays (Woorinen Formation) along with siliceous sands derived from the Parilla Sand (Lowan Sand). Of these east-west trending siliceous deposits, the Lowan sands form extensive toungue-shaped dunefields of the Little Desert and Big Desert.

#### *Today's climate, salinity and groundwater processes*

Climates during greatest weathering and erosional events prior to the Late Miocene indicate that a cool to temperate and presumably humid climate resulted in development of a Mesozoic palaeosurface (Hills 1975; Ollier & Pain 1994). Since then considerable erosion has seen few palaeo geomorphological features retained with the Palaeogene dominated by tropical climates (Evans, Campbell & Kellet 1990). Relative wet conditions were to follow until the retreat of the last sea incursion where conditions became drier. Dry to wet cyclic changes have occurred ever since with fluctuations in lunette building phases intermixed with wet periods or high watertable and lake levels indications of these changes.

### *Land hazards*

Rockfalls in the Grampians Ranges occur from time to time and are associated with large scarps of these cuesta landscapes. Likewise, granite landscapes including Ben Nevis and the Black Range have large boulders and tors that potentially pose risks in extreme events (e.g. high wind/rainfall events, frost heaving).

Landslips are uncommon but occur in the region. Slip scars are evident on the south facing scarp of the Mount Difficult Range near Halls Gap (Cayley & Taylor 2001) along with small slips on the Concongella Hills, Mount Moornambool, Mount Ararat and Rocky Point. An example of an active landslip occurs just south of the catchment boundary in the prominent slump on the western face of Mount Moornambool. This slump composed of red saprolite is a significant landscape feature and highlights potential land hazards.

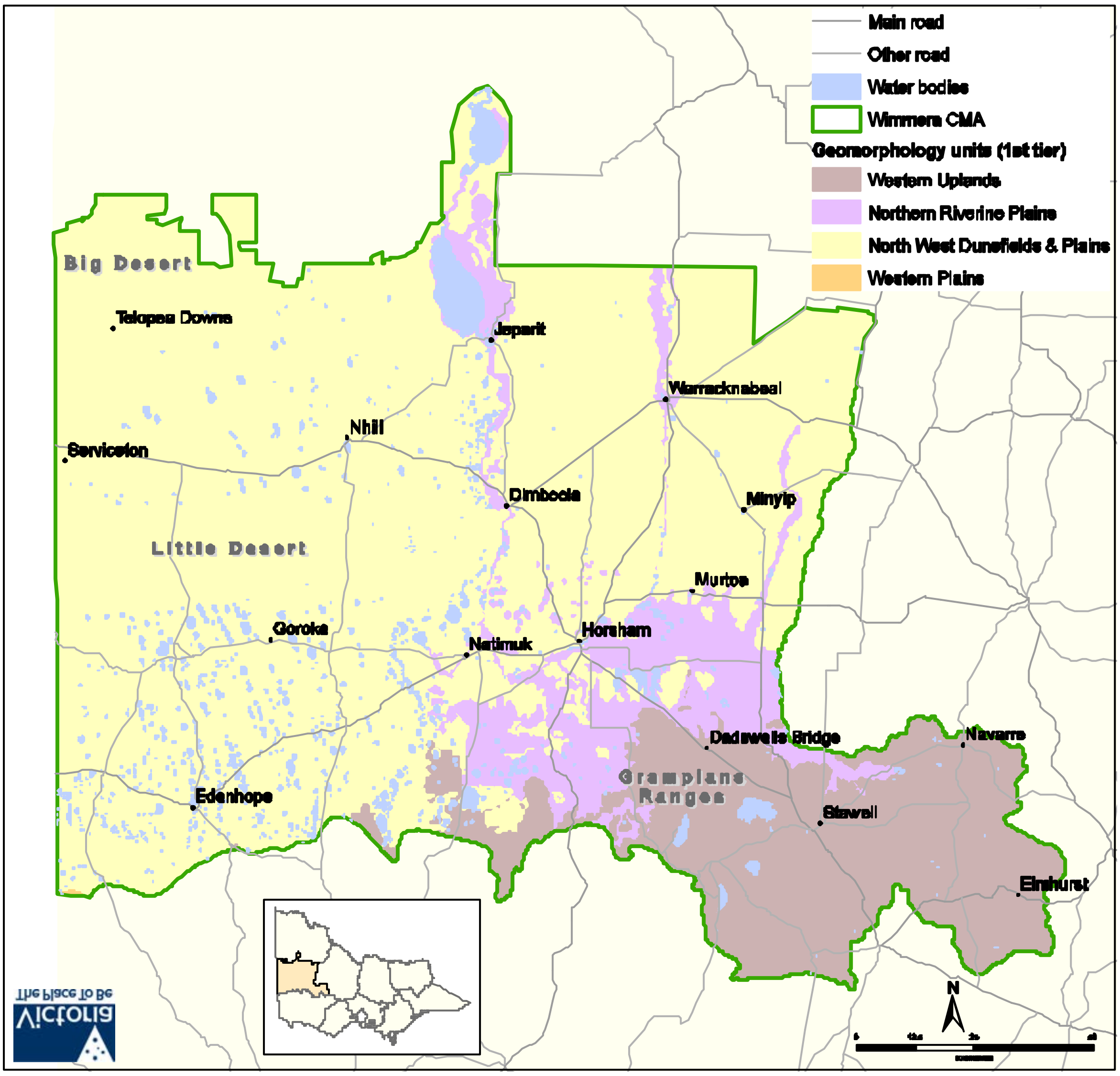



Figure 3  First geomorphological units of the WCMA region

## 2.2 Geomorphic framework for the Wimmera region

The physiography of the WCMA region reflects the underlying geology and landscape evolution processes. The four main first division units of the WCMA region are:

- Western Uplands
- Northern Riverine Plain
- North West Dunefields and Plains
- Western Plains

These first tier geomorphic units (Figure 3) are further delineated into a range of second tier geomorphological units. Second tier units are further divided into a larger range of third tier geomorphological units. The geomorphological tiers that form the basic components of this land resource assessment of the WCMA region are as follows:

# 2 Western Uplands

### 2.1 Dissected uplands (formerly Midlands)

2.1.1 Ridges, escarpments, mountains on non-granitic Palaeozoic rock (Pyrenees Ranges, Ararat Hills)

2.1.2 Hills, valley slopes and plains on non-granitic Palaeozoic rock (Concongella hills, Mount Dryden)

2.1.3 Ridges, escarpments, mountains on granitic Palaeozoic rock (Langi Ghiran, Black Range – Mount Sugarloaf)

2.1.4 Hills, valley slopes and plains on granitic Palaeozoic rock (Wartook, Rocky Point)

2.1.5 Plateaux and rises of residual Cainozoic landscapes (Great Western, Glenorchy)

2.1.6 Eruption points, volcanic plains and plateaux (Barton)

2.1.7 Terraces and floodplains (Mount Cole Creek, Mount William Creek)

### 2.2 Strike ridges and valleys - Grampians Ranges

2.2.1 Cuesta landscapes (Mount Difficult Range, Mount William Range)

2.2.2 Sandstone hills (Black Range)

2.2.3 Valleys, alluvial terraces and floodplains (Halls Gap)

### 2.3 Low elevation plateaux (tablelands)

2.3.1 High relief, low drainage density (Western Dundas Tableland – Harrow)

2.3.2 Low relief, low drainage density (Eastern Dundas Tableland – Brimpaen)

# 4 Northern Riverine Plains

### 4.1 Modern floodplains (Coonambidgal Formation)

4.1.1 Meander belt below plain level, sometimes source-bordering dunes (Yarriambiack Creek)

4.1.2 Areas of inundation away from modern channels (Yarriambiack Creek)

### 4.2 Older alluvial plains (Shepparton Formation)

4.2.1 Plains with leveed channels, sometimes source-bordering dunes (Wal Wal, Murtoa, Corkers)

4.2.2 Plains without leveed channels (Wimmera River – Drung)

4.2.3 Lakes and basins with lunettes (Lake Hindmarsh, Lake Albacutya)

### 4.3 Pediments, alluvial fans and aprons (Horsham south)

## 5 North West Dunefields and Plains

### 5.1 Calcareous dunefields (Woorinen Formation)

5.1.3 Linear dunes sub-dominant (Lowan salt valley, Antwerp)

5.1.5 Hummocky dunes sub-dominant (Hopetoun, Peppers Plains)

### 5.2 Siliceous dunefields (Little Desert, Big Desert)

5.2.1 Parabolic dunes

5.2.2 Linear dunes

### 5.3 Depressions

5.3.3 Salt lake depression (Douglas Depression)

### 5.4 Clay plains with subdued ridges (Minyip)

### 5.5 Ridges with sand, and flats

5.5.1 Prominent ridge tops with remnant aeolian sands and orientated swales with lakes and lunettes (north of Little Desert – Diapur, Kiata)

5.5.2 Low ridge tops with remnant aeolian sands and oriented swales with lakes and lunettes (south of Little Desert – Kowree, Goroke)

5.5.3 Prominent ridges with eroded ferruginised northern spurs (south of the Lower Norton Wimmera Bridge - Darragan)

### 5.6 Hills and low hills (Mount Arapiles)

## 6 Western Plains

### 6.2 Sedimentary plains (unconsolidated sedimentary deposits)

6.2.1 Plains with depositional ridges (Kanawinka)

## 2.3 Terminology used for 3rd tier geomorphological units in this report

The third tier descriptions have been modified as follows in this report in order to clarify their context in the geomorphological framework.

**2 Western Uplands**

2.1.1 Ridges, escarpments and mountains on non-granitic Palaeozoic rock of the Dissected Western Uplands
2.1.2 Hills, valley slopes and plains on non-granitic Palaeozoic rock of the Dissected Western Uplands
2.1.3 Ridges, escarpments and mountains on granitic Palaeozoic rock of the Dissected Western Uplands
2.1.4 Hills, valley slopes and plains on granitic Palaeozoic rock of the Dissected Western Uplands
2.1.5 Cainozoic landscapes of the Dissected Wester n Uplands
2.1.6 Eruption points, volcanic plains and plateaux of the Dissected Western Uplands
2.1.7 Terraces and floodplains of the Dissected Western Uplands
2.2.1 Cuesta strike ridges and valleys (Grampian Ranges)
2.2.2 Sandstone hill strike ridges and v alleys (Grampian Ranges)
2.2.3 Terraces, fans and floodplains of strike ridge and valleys (Grampian Ranges)
2.3.1 High relief, low drainage density low plateaux (tablelands)
2.3.2 Low relief, low drainage density low plateaux (tablelands)

**4 Northern Riverine Plains**

4.1.1 Meander belt below plain level of the Modern floodplains
4.1.2 Areas of inundation away from channels of the Modern floodplains
4.2.1 Plains with leveed channels of the Older alluvial plains
4.2.2 Plains without leveed channels of the Older alluvial plains
4.2.3 Lakes and basins with lunettes of the Older alluvial plains
4.3 Pediments, alluvial fans and aprons (Glencoe, Yallambee)

**5 North West Dunefields and Plains**

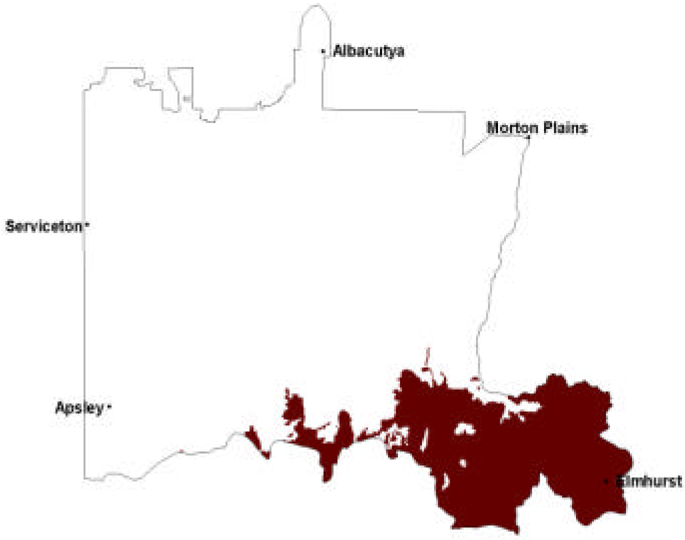
5.1.3 Linear dunes sub-dominant of the Calcareous North West Dunefields and Plains
5.1.5 Hummocky dunes sub-dominant of the Calcareous North West Dunefields and Plains
5.2.1 Parabolic dunes of the Siliceous North West Dunefields and Plains
5.2.2 Linear dunes of the Siliceous North West Dunefields and Plains
5.3.3 Salt lake depression of t he North West Dunefields and Plains
5.4 Clay plains with subdued ridges of the North West Dunefields and Plains
5.5.1 Prominent ridges and orientated swales of the North West Dunefields and Plains
5.5.2 Low ridges and oriented of the North West Dunefields and Plains
5.5.3 Prominent ridges with eroded ferruginized northern spurs of the North West Dunefields and Plains
5.6 Hills and low hills of the North West Dunefields and Plains

**6 Western Plains**

6.2.1 Plains with ridges of the Western Sedimentary Plains

Soil-landform units for each geomorphological group (3rd tier) are provided in tables that accompany a written description of the geomophological group. Included are the soil-landform unit identification, an abbreviated unit description and location, along with unit area.

# 2 Western Uplands




The Victorian Western Uplands constitute the western extent of the Victorian Highlands (Hills 1940) or Central Victorian Uplands (Jenkin 1988) as distinct from the Eastern Victorian Uplands (Jenkin 1988), extending west of the Kilmore Gap (a geocol) to the western edge (Glenelg River) of the Dundas Tableland. They have been divided into the dissected uplands (2.1), sometimes referred to as the Midlands (Hills 1940; Jenkin 1988; Taylor et al. 1996); the strike ridges and valleys of the Grampians Ranges (unit 2.2); and the tablelands (2.3), including the Dundas, Merino and Stavely tablelands.

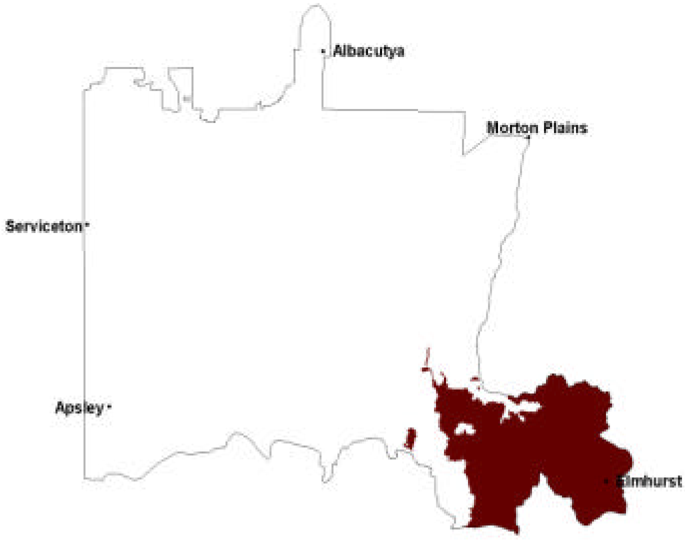
The terrain is characterised by a suite of Palaeozoic bedrock formations that are expressed as residuals from differential erosion of extensive mountain masses. Landscapes are typically asymmetrical with gentle northern slopes and youthful dissection of southern slopes (Hills 1975). Resistant rock residuals include the granitic Harcourt batholith (Mount Alexander and Harcourt), Cobaw Ranges, Mount Buangor and Mount Langi Ghiran; the rhyodacite massif of Mount Macedon; metamorphic ridges of Mount Tarrangower and Big Hill; Palaeozoic marine sediments of the Pyrenees Ranges and Trentham Dome; or the stratigraphic succession of quartzo-feldspathic sandstones of the Grampians Ranges.

The Western Uplands is a topographically lower composite of landscapes than those of the Eastern Uplands and is a broad, dome-like elongated east to west low-relief drainage divide having an average elevation of only 300 m (Joyce et al. 2003). The highest summits and mountains include Mount Macedon (1001 m) and Camels Hump (1011 m), Mount William (1167 m), Mount Buangor (966 m) and Mount Langi Ghiran (922 m). No high plains occur owing to the low elevation of these peaks, however remnants of the broader Mesozoic palaeosurface have been retained at lower elevations. Remnants of this surface include the plateaux of Mount Cole and Mount Buangor, Mount Macedon, Mount Alexander and the Major Mitchell Plateau. Beneath the Mesozoic palaeosurface, an extensive Cainozoic palaeoplain surround north, west and southerly extents of the Western Uplands. Localised dissection combined with tectonic activity has formed north-south and east-west fault scarps and monoclines, and broad domal uplifts (Joyce 1992) leaving dissected landscapes of the Brisbane and Blackwood ranges with extensive gorges (e.g. Lerderderg Gorge) and valleys (e.g. Parwan Valley). Volcanic plains also occur within the Midlands with numerous scoria cones prominent within these subdued landscapes. Recent stream dissection has stripped regolith and deposited material as alluvial deposits and colluvial aprons that fringe the Western Uplands.

The main divide separates north flowing from the south flowing streams that have much steeper gradients owing to their closer proximity to the Victorian coastline. The divide is ill defined (Hills 1975) due to extensive weathering of landscapes leaving ranges and ridges with extensive valley systems that don't reflect the defined ridge and valley relief of the Eastern Uplands. Drainage systems flowing north as part of the Murray Darling Basin include the Campaspe, Loddon, Avoca, Wimmera, Avon and Richardson rivers while streams flowing towards the southern Victorian coastline include the Glenelg River, Wannon River, Hopkins River, Fiery Creek, Woady Yaloak Creek, Moorabool River, Leigh River, Werribee River, Maribynong River, Merri Creek, Kororoit Creek and Little River.

In the WCMA region all three divisions of the Western Uplands occur with the Dissected Uplands (Midlands) and the strike ridges and valleys of the Grampians Ranges prominent.

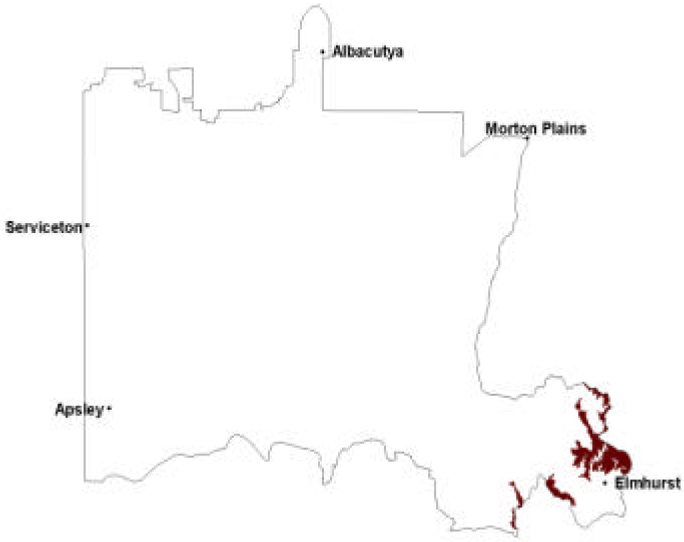
## 2.1 Dissected uplands (formerly Midlands)




The dissected uplands are characterised by a variety of ridges, plateaux and hills developed on Cambro-Ordovician volcanic, sedimentary and metamorphic rocks (Joyce et al. 2003). Landforms have been interwoven and preserved through substantial tectonic uplift during the Palaeogene (Carey & Hughes 2002) and late Neogene (Taylor et al. 1996).

Undulating hills, rises and broad valleys are major landform patterns delineated in Palaeozoic sedimentary rocks and negative/positive relief granite plutons and batholiths. Later lining of hillslopes, crests and valley deposits of Cainozoic sediments (predominantly gravels) are sporadically preserved throughout these uplands. Volcanic activity during the Plio-Pleistocene saw large basalt flows migrate southwards forming large gentle to undulating basalt plains. Recent dissection of the landscape through sea level fluctuations has seen Quaternary deposition of aeolian and alluvial sediments in upper reaches of rivers and streams.

## 2.1.1 Ridges, escarpments and mountains on non-granitic Palaeozoic rock (Pyrenees Ranges, Ararat Hills))




The ridges, escarpments and mountains are located within the upper catchments of the Wimmera River, Mount William Creek and Mount Cole Creek drainage networks. Occurring throughout the Midlands (including the North Central and Glenelg Hopkins CMA regions), these landscape features often adjoin the hills, rises and plains of similar broad geological lithologies. The Ararat Hills with the Pyrenees Ranges are examples of these Palaeozoic rock landforms.

The topography of the Pyrenees Ranges becomes more subdued in the north-west where it merges with the Avon plains to the south-west and south-east. Major ridges are orientated along a strike (north-west) with rectangular stream channel patterns that are generally orientated in a north-east orientation that often reflect jointing and faulting. Hillslopes are generally greater than 20% with the very steep deeply dissected hillslopes (> 56%) of the Pyrenees Ranges located near Glenpatrick. The highest peak within the WCMA region is Blue Mount (763 m).

The Ararat Hills occur as four parallel high ridges extending from near Great Western to Mount Chalambar, and are significant landscape elements with highest peaks including Mount Ararat (618 m) and One Tree Hill (579 m). Stream channel patterns of these ridges reflect the narrow linear orientation of the strike ridges with drainage unidirectional until drainage converges on the lower slopes of neighbouring rises and plains. Hillslopes are more subdued that the slightly steeper terrain of the Pyrenees Ranges with very steep slopes (> 56%) confined to upper slopes surrounding the summit of Mount Ararat.

The bedrock ridges, fault scarps and monoclines (Joyce 1992) of sedimentary rocks largely consist of sandstones, shales and mudstones that have been intensively folded and faulted in Post-Ordovician times. Later regional and contact metamorphism events saw alteration into metasediments including slates, hornfels, and schists with significant loads of quartz (some gold bearing) as reefs and veins (Sibley 1967).

These landscape elements through differential erosion are remnants of a deeply weathered Palaeogene palaeosurface with rock outcrops fewer and smaller in the north-west of the upper catchment reaches. Depth of regolith is irregular across these landscapes, however the depths are more consistent than sedimentary landscapes with southerly aspects further east. Pallid kaolinitic profiles are often up to 15 m thick with residual ferricrete and reef quartz (Joyce 1992; Taylor & Joyce 1996; Joyce 1998; Carey & Hughes 2002). In some areas, remnants of Palaeogene weathering in the form of siliceous and ferruginous duricrusts are preserved by the inversion of relief and development of structurally bound drainage networks.

Soils that have developed on these landforms are red texture contrast soils (Chromosols) that may be sodic (Sodosols) especially where rainfall is lower and in lower topographic positions. Slightly acidic, they often tend to neutral with depth. Structured surfaces overlie sporadically bleached horizons with variable amounts of coarse weathered bedrock fragments and quartz. Lower slopes have deeper profiles including red-mottled brown and yellow variants.

Heathy Dry Forest and Grassy Dry Forest are found mostly in exposed areas of the Pyrenees Ranges and Ararat Hills, while Herb-rich Foothill Forest, Grassy Dry Forest and Valley Grassy Forest are more closely associated with sheltered steep to very steep hillslopes and drainage lines. Other vegetation communities recorded include Rocky Outcrop Shrubland on ridge crests, Hillcrest Herb-rich

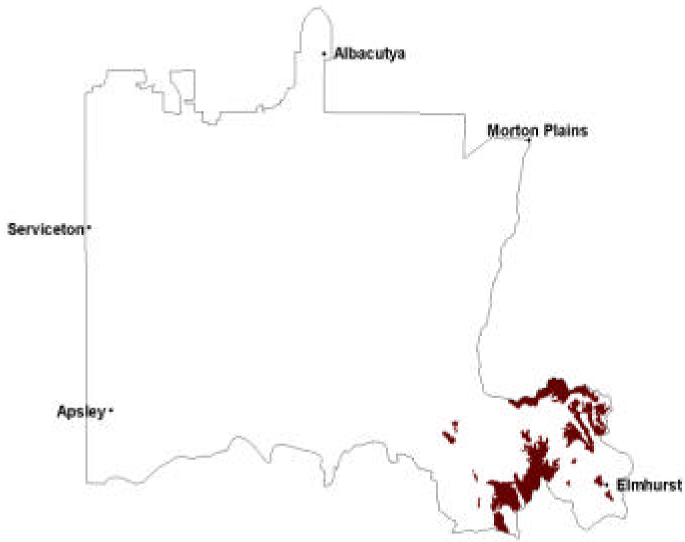
Woodland, Box Ironbark Forest, Alluvial Terraces Herb-rich Woodland and Grassy Woodland on lower slopes and drainage lines.

As high elevation areas within the WCMA region, hillslopes and crests are considered high rainfall recharge areas with little to no saline discharge within landscapes. Landslides have been observed as slip scars in the Ararat Hills (on the south-eastern slopes of Mount Ararat) where land was cleared as part of historic pastoral runs. The fractured nature of these folded and fractured rocks permits large volumes of groundwater to be stored, and removed from the system usually as break-of-slope events within these local systems.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Ararat Hills | Strike ridge hills | 55 |
| Pyrenees Ranges | Mountains | 237 |

Figure 4 Strike ridges of the Pyrenees Ranges

## 2.1.2 Hills, valley slopes and plains on non-granitic Palaeozoic rock (Concongella Hills, Mount Dryden)




Lower in the topographic sequence than the ridges, escarpments and mountains of the Midlands (dissected uplands) are the neighbouring hills, valley slopes and plains of the upper Wimmera catchment. These eroding landscapes occur from Mount Dryden in the west to the fringing hills of the Pyrenees Ranges in the east. Comprising strike ridges and valleys, (complexs of hills and low hills intermixed with surrounding rises and plains) to rises and a broken chain of low hills in the Mount William Creek catchment, the undulating to steep topography of these landscapes provide a fundamental link between the mountainous terrain of the Pyrenees Ranges and Ararat Hills to the alluvial drainage plains of the Wimmera River and Mount William Creek.

These landscapes are more subdued than those of the Pyrenees and Ararat Hills and are distributed as isolated hills in the west compared to the larger coherent landscapes in the south and east of the upper Wimmera catchment. Slopes can be variable from steep hill slopes to lower slopes and footslopes, however slope segments are often considerably longer than those of the Pyrenees Ranges. Stream channel drainage is quite varied reflecting the suite of landform patterns within the region.

The Mount Dryden Hills are a sequence of isolated low hills to the east of the Grampians Ranges. Trending north-westerly, these hills are 60–100 m higher the surrounding alluvial plains. Slopes are steep with the topography of these hills being more subdued in the south where slopes tend to be moderately to gently inclined. Mount Dryden is the highest (382 m) and largest outcrop, and due to the isolated nature of outcrops has radial drainage patterns that feed into Mount William Creek. In the upper reaches of Mount Cole Creek and the Wimmera River, low hills occur as isolated outcrops adjacent to neighbouring granite plutons. Slopes here are moderate to gentle with little significant relief.

The Concongella Hills are surrounded by a suite of landforms that underlie these topographically prominent features. Low hills, rises, plains and drainage depressions are common within this landscape complex that is bound to the east by the Wimmera River/Mount Cole Creek and by Mount William Creek in the west. Hillslopes are steep to moderately inclined with the remaining slopes of the landscape gently inclined. Drainage is dendritic away from the hills where radial drainage is dominant.

Extensions of the Pyrenees Ranges in the east of the upper Wimmera catchment include hills east of Joel South. Here upper slopes are steep with long gently inclined lower slopes that converge into footslopes and rises that line Wattle Creek and Howard Creek.

The Mount Dryden Hills are a fault-controlled belt of volcanic rocks (calc-alkaline andesitic and dacitic lava, intrusives and fine grained volcaniclastics) striking north-north-westerly (Cayley & Taylor 2001). Cainozoic ferruginised ironstone flank many slopes of these hills.

Further in the east, the landscapes are composed of sedimentary rocks that have been folded and faulted in post-Ordovician times. Metasediments that have experienced low grade regional metamorphism can be observed in the subdued strike ridges to undulating hills of the Concongella Hills and surrounding landforms. Weathering is variable with pallid kaolinitic profiles tending to be deeper on areas of lower relative relief than topographically pronounced landforms are (e.g.

mountains, escarpments). Palaeogene remnants (ferruginous duricrusts) are common on hillslopes and crests of low hills/rises.

Red texture contrast soils (Chromosols) that tend to be sodic (Sodosols) in lower topographic positions have developed on hills, valley slopes and plains. Surfaces are lightly textured well structured soils that have a sharp contrast with the medium to heavy subsoils that have vastly slower infiltration rates. While slightly acidic at the surface, they become alkaline at depth with profiles on lower slopes having deeper profiles than steeper upper slopes. Variable amounts of coarse weathered bedrock fragments and quartz occur throughout the profile.

Vegetation communities reflect variation in climate, aspect, geology and morphology. The Mount Dryden Hills have Heathy Woodland, Plains Grassy Woodland and Shrubby Woodland found on well drained soils. Vegetation communities such as Creekline Grassy Woodland and Seasonally Inundated Shrubby Woodland are found on lower slopes and drainage depressions.

The Concongella Hills and Rhymney low hills area has remnant vegetation dominated by forest and woodland areas. The main vegetation communities include Heathy Dry Forest, Grassy Dry Forest, Grassy Woodland, Plains Grassy Woodland, Alluvial Terraces Herb-rich Woodland and Heathy Woodland. Creekline Grassy Woodland occurs in the lowest positions of these landscapes. Granitic Hills Woodland can also be located on these non-granitic landforms.

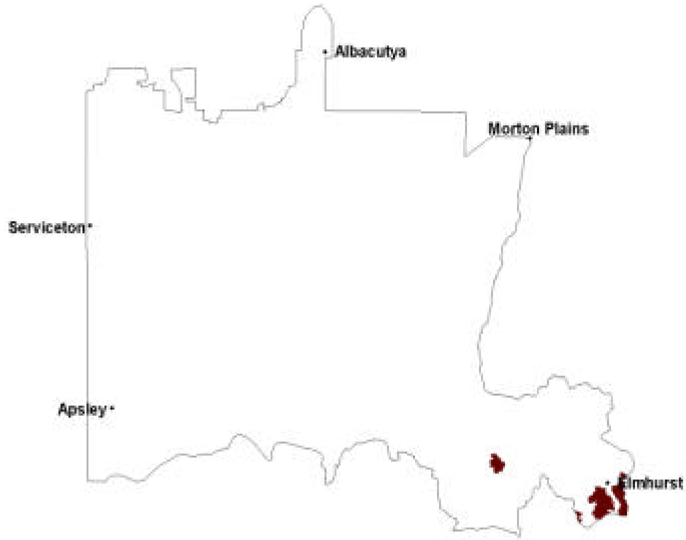
Adjoining the Pyrenees Ranges, remnant forest and woodland areas dominate vegetation. Heathy Dry Forest, Grassy Forest, Box Ironbark Forest and Grassy Dry Forest are found in exposed areas, Hillcrest Herb-rich Woodland, Grassy Woodland, Creekline Grassy Woodland and Plains Woodland found in more sheltered areas, or in areas at higher altitudes.

The Concongella Hills are an extremely vulnerable landscape to erosion and dryland salinity. Gully and tunnel erosion, and sheet and rill erosion are common on moderate to steep slopes especially where remnant vegetation has been removed for grazing purposes. Landslides and mud flows are likely where steep to very steep slopes occur, especially on lower peripheral landscapes within the Pyrenees Ranges.

Salinity processes within the metasediments of the upper catchment are driven by local to intermediate groundwater flow systems within fractured bedrock. Groundwater processes operate within the top 50–100 m of the landscape where groundwater discharge often occurs at the break-of-slope. Bedrock of lower relief partially discharges within the upper catchment with salinity levels derived from vast salt stores varied between 3000 mg/l to 12 000 mg/l (WCMA 2005).

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Concongella Hills | Hills | 69 |
| Elmhurst footslopes | Hillslopes and footslopes | 8 |
| Joel South hills | Hills | 43 |
| Kanya hills | Low hills | 13 |
| Landsborough footslopes | Plains and footslopes | 115 |
| Mount Dryden metamorphic hills | Metamorphic hills | 21 |
| Navarre foothills | Foothills | 117 |
| Rhymney hills | Undulating low hills | 183 |
| Surridge foothills | Footslopes and foothills | 58 |

## 2.1.3 Ridges, escarpments, mountains on granitic Palaeozoic rock (Langi Ghiran, western Black Range – Mount Sugarloaf)




Ridges, escarpments and mountains of granitic origin can be found within the highest reaches of the Wimmera River and Mount Cole Creek. These granitic plutons are scattered throughout the Midlands and form prominent hills and mountains that rise above their surrounding metamorphic aureoles and other areas of country rock (Joyce et al. 2003).

The positive relief plutons such as Langi Ghiran (922 m), formerly known as Larne Gerin (Hills 1975), Ben Nevis (879 m) and the western Black Range (559 m) form prominent hills and mountains that rise above surrounding metamorphic aureoles and alluvial drainage systems. Tors and boulders of granite and larger granite outcrops represent whalebacks on their flanks (Cayley & MacDonald 1995). The slabby cliffs that rise above rock overhangs (whaleback) of Ben Nevis are the largest developed in Victoria.

Significant plateau remnants are preserved on the Mount Buangor Range with very minor segments preserved on Langi Ghiran. The plateaux have low gradients with moderate to gently inclined slopes with streams that drain these surfaces. Margins of the plateaux are steep to very steep with radial drainage away from these plutons.

Granitic landscapes within the WCMA region comprise granite plutons belonging to three suites (Mount Cole, Glenlogie and Ararat) that approximately intruded 390 million years ago (White & Chappell 1983) as part of the Lachlan Fold Belt plutonism events. These granitic masses that have been stripped of ancient palaeosurface materials have left pronounced topographic features (plateaux) on steep to precipitous slopes. Plateau remnants, considered to be early Mesozoic in age (Hills 1940; King 1959), are the oldest surviving geomorphological features of the WCMA region.

The Langi Ghrian Granite, Ben Nevis Granite and Mount Cole Adamellite all form part of the Mount Cole Suite within the Stawell Province of the Whitelaw Terrane. Regolith is relatively shallow to non-existent on steeper slopes with deeper profiles occupying plateau cappings. The Black Ranges are derived from the Stawell Granite where little regolith exists and is dominated by rocky outcrop.

The granites generally have developed sandy soils, with profiles varying from uniform or weakly gradational sands (Kandosols) to strongly texture contrast ferruginised ('buckshot' or iron pan) soils (Chromosols and Kurosols). The yellow texture contrast soils are strongly acidic at the surface, becoming slightly acidic or neutral at depth. Weakly structured surfaces overlie a massive horizon with variable amounts of coarse quartz fragments. Subsoils are medium to heavy clays often with conspicuous mottling. Total soil depth is variable depending upon differential weathering but generally increase with decrease in topographic position.

Vegetation is dominated on the Mount Cole Granitic Suite by Grassy Dry Forest. Other vegetation communities present include Herb-rich Foothill Forest, Hills Herb-rich Woodland, Grassy Woodland and Alluvial Terraces Herb-rich Woodland/Plains Grassy Woodland Complex. The Black Range has a similar variety of remnant vegetation communities, however it is more exposed to prevailing winds from the north, south and west. Riparian Scrub, Shallow Sands Woodland, Creekline Grassy Woodland and Heathy Woodland are variants.

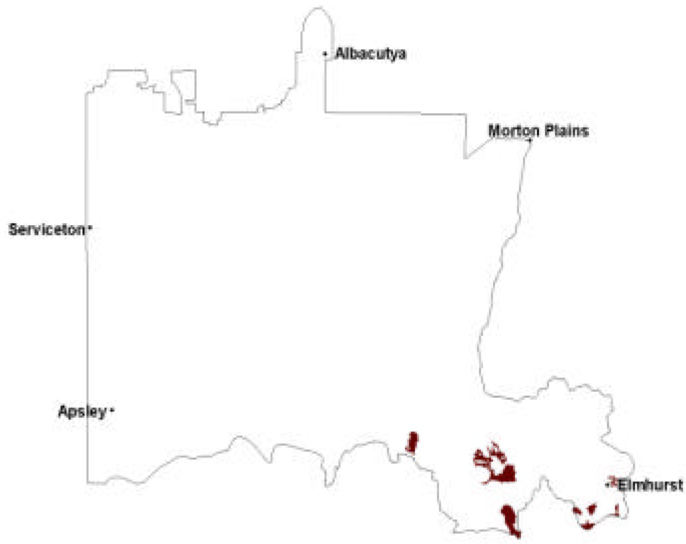
Groundwater migrates through aquifers comprising either abundant colluvium found on slopes or underlying weathered and fractured/jointed bedrock. Shallow perched groundwater through lateral flow migrates downslope and discharges at the break-of-slope or feeds into basal aquifers that underlie adjacent valleys (WCMA 2005).

The eroding granitic slopes are extremely vulnerable to extreme rainfall events in the form of sheet and rill erosion. Landslides and mud flows can eventuate where extreme rainfall events are coupled with land clearance and steep slopes. Landslips and mudflows occur where saturated soils fail.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Langi Ghiran ranges | Granitic mountains | 121 |
| Sugarloaf granite hills | Granitic hills | 26 |

Figure 5  Eastern Black Range, south of Stawell

## 2.1.4 Hills, valley slopes and plains on granitic Palaeozoic rock (Wartook, Rocky Point)




The granite plutons away from the steep and topographically prominent landforms (Langi Ghiran, western Black Range) are generally subdued hills, low hills and plains with deeply weathered bedrock (such as those at Rocky Point) and the footslopes surrounding prominent mountains and escarpments.

These subdued plutons (often referred to as negative relief) such as the Ararat Granodiorite (Rocky Point at over 550 m) forms topographically lower relief landscapes when compared to the higher relief metamorphic aureoles (e.g. Mount Ararat 618 m) that surround the pluton. Erosion has seen the unroofing of these plutons from late Palaeozoic time to leave exposures seen today. Slopes are typically moderately to gently inclined with variable weathering producing tors and boulders through to thick kaolin clays. Tributaries are prevalent where saprolite is deepest and ultimately contribute surface and groundwaters into the Wimmera River, Mount Cole Creek and Mount William Creek systems.

The subdued granites are more susceptible to weathering owing their accelerated erosion to higher biotite concentrations and lesser plagioclase than more prominent granitic landscapes (Hill 1992, 1996). Large concentrations of transported residual sand blanket much of the underlying bedrock while in places the regolith is characterised by deep kaolin deposits that are often overlain by later Cainozoic sediments.

Soil profiles with sandy surfaces and strongly texture contrast are common on these granite landscapes. Sodic yellow texture contrast soils are strongly acidic at surface, becoming slightly acidic or neutral at depth. Conspicuously bleached subsurface horizons overlie medium to heavy clays that act as a hydraulic throttle to water movement through the soil profile. Lighter weathered material often occurs under these clays. Soils are generally deeper than those of Langi Ghrian and the western Black Range.

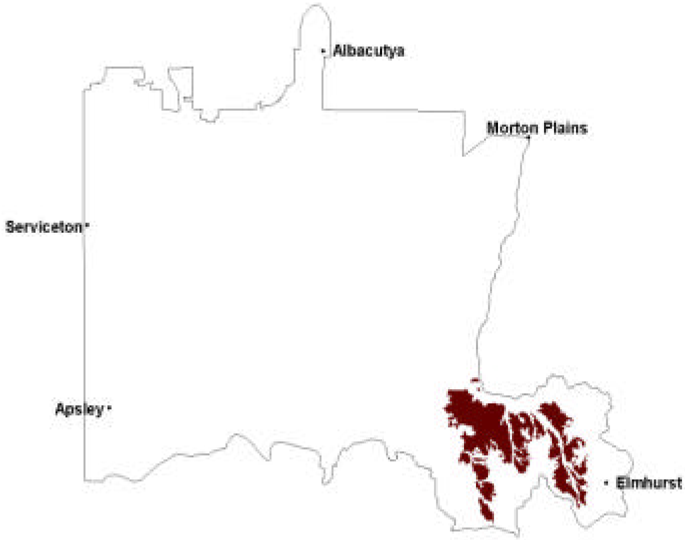
Vegetation communities include Grassy Dry Forest, Granitic Hills Woodland, Grassy Woodland, Herb-rich Woodland, and Granitic Hills Woodland on more exposed slopes where Alluvial Terraces and Herb-rich Woodland occupy lower slopes and drainage depressions.

Saline discharge occurs at the break-of-slope as perched groundwater moves laterally downslope through colluvium of footslopes and foothills. Occasionally this groundwater contributes to underlying basal aquifers in valleys.

Granitic slopes are prone to sheet and rill erosion from extreme rainfall events. Landslides and mud flows can eventuate where significant rainfall is combined with land clearance and steep slopes causing soils to fail (e.g. Rocky Point).

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Langi Ghiran colluvial footslopes | Colluvial footslopes | 35 |
| Rocky Point low hills/rises | Undulating rises and low hills | 42 |
| Sugarloaf granite hills | Granitic hills | 88 |
| Wartook granite hills | Moderate-steep hills | 23 |

## 2.1.5 Plateaux and rises of residual Cainozoic landscapes (Great Western, Glenorchy)




Widespread deposition of sands and gravels are preserved as fringing sheets of capping material across Palaeozoic sediments and granitic terrains of the upper Wimmera catchment. They are significant due to their preservation of underlying bedrock as resistant ferricrete and silcrete. Examples include the undulating rises near Great Western and gentle to undulating plains from Deep Lead to Glenorchy and Mokepilly.

Undulating rises and plains characterise the landform patterns of these Cainozoic landscapes. Generally the rises that are often capped with Cainozoic sands and gravels sit in a lower topographic position in comparison to neighbouring low hills and hills of granitic plutons and Palaeozoic bedrock. The extensive rises that fringe many of the higher landscapes, as well as lining alluvial valleys and flats, often occur as discontinuous landforms with gently to very gently inclined slopes of 5–30 m relief.

More subdued landscapes along Mount William Creek include level to undulating plains that have long gentle slopes (usually < 5%). Drainage is infrequent and is primarily confined to areas with slightly more relief than the sandy plains of Mokepilly between Lake Lonsdale and Lake Fyans. Little to no bedrock is exposed across these gentle slopes.

These Palaeogene and Neogene deposits (known as the Great Western Group, Denicull Formation and Parilla Sand) are generally preserved as hilltop capping ('ironstone'), upper slopes of bedrock ridges and extensive planar landforms that mimic duricrust landscapes associated with the Dundas Tableland and Brimpaen landsystem (Sibley 1967).

The Great Western Formation (or White Hill equivalents) has been found between 220 and 290 mAHD in the upper Wimmera catchment (Hocking 1997). Laying above current alluvial deposits, the gravels are the erosional remnants of prominent fluvial systems that were active through much of the Western Uplands. Deposit thickness varies from less than 1 m to in excess of 15 m on footslopes/terraces/rises of the Wimmera River valley and other terrain (e.g. Rocky Point undulating rises). Size and compositional sorting of the gravels is poor (Cayley & MacDonald 1995) with quartz reef derived clasts located within a matrix of fine to very coarse sand, minor silt and clay.

Deposition of these sediments is often followed by deep weathering including ferruginisation/silicification, and kaolinisation of underlying Palaeozoic bedrock (Taylor & Joyce 1996). This can be observed today as inverted landscapes through preferential denudation (e.g. deep lead development).

Later activity in the Neogene saw the retreat of the sea from the Murray Darling Basin and deposition of fine to coarse-grained quartz sands as sand ridges and beach relicts (shoreline dunes). The Parilla Sand deposits form subparallel ridges that are often ferruginised and are more commonly expressed in the Millicent Coast Basin area of the WCMA region.

Developed on these sediments are a suite of texture contrast soils (yellow, brown, red; sodic and non-sodic) and red gradational or uniform soils.

The yellow and brown texture contrast soils (Sodosols and Chromosols) are often associated with Kandosols where soils are slightly acidic at the surface but become neutral or alkaline at depth. Brown sandy loams overlie conspicuously bleached massive loamy sands with variable amounts of coarse quartz fragments. Mottled yellowish brown medium clays provide a sharp texture change from above material. The brown to red texture contrast soils are similar with pronounced red subsoil mottling and ferruginous nodules (buckshot) common in the bleached subsurface horizon.

Red gradational or uniform soils are acidic profiles with brown sandy loam surfaces containing variable amounts of coarse quartz fragments. This gradually changes to yellowish red sandy clay that also has quartz gravels. This soil has a greater capacity for water infiltration and drainage than the texture contrast variants.

Undulating landscapes dominated by sandy deposits have main vegetation communities including Heathy Woodland to Box Ironbark Forest and Plains Sedgy Woodland. Other vegetation communities present include Plains Grassy Woodland, Grassy Woodland, Grassy Woodland/Heathy Woodland Mosaic, Plains Woodland and Drainage-line Woodland. Landscapes further up Mount William Creek (including the plains at Mokepilly and undulating rises at Bellellen) have Heathy Woodland and Plains Grassy Woodland also with variants including Damp Sands Herb-rich Woodland, Red Gum Wetland, Heathy Dry Forest, Sedge-rich Woodland, Shallow Freshwater Marsh, Shallow Sands Woodland and Lateritic Woodland.

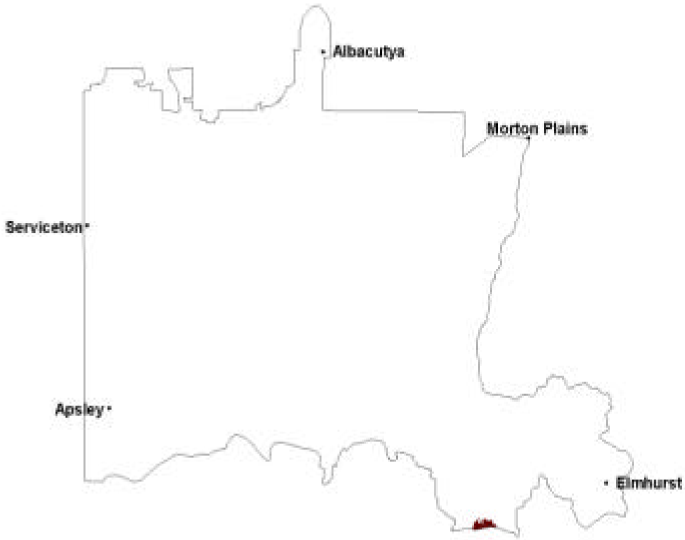
Landscapes dominated by gravels intermixed with sand, silt and clays include the vegetation communities Heathy Dry Forest, Grassy Dry Forest, Heathy Woodland, Plains Grassy Woodland, Alluvial Terraces Herb-rich Woodland, Grassy Woodland, Plains Woodland and Creekline Grassy Woodland.

The deeply weathered nature of these landscapes represents groundwater systems that are very slowly permeable generally owing to significant kaolin deposits with high salt stores. Saline discharge often occurs as localised events or subartesian in lower landscape positions. Gully and tunnel erosion are prominent on moderate to gentle slopes. It is often a combatant or by-product of saline discharge mechanisms that lead to exposure of vulnerable sodic subsoils and ultimately erosion.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Bellellen undulating rises | Undulating low hills and rises, footslopes and foothills | 139 |
| Glenorchy rises | Dissected plains | 249 |
| Great Western rises | Foothills and footslopes | 412 |
| Howard Creek plains | Dissected plains | 32 |
| Mokepilly undulating plains | Undulating plain | 33 |

Figure 6 Undulating plains and rises with creeks and erosion scars near Salt Creek

## 2.1.6 Eruption points, volcanic plains and plateaux (Barton)




Undulating basalt plains within the WCMA region are confined to the upper reaches of the Mount William Creek catchment. The plains near Barton lead to vast, broad lava flows of the Western Plains. The plains have historically been cleared as part of significant pastoral runs of Western Victoria (e.g. Barton Station).

Lava flows filled many of the valleys east of Moyston leaving a gently to severely undulating topography of plains, low rises (including stony) and swamps. Drainage systems of the plains are poorly developed and have been supported by a series of engineered drains to remove excess surface water for grazing and cereal cropping. The basalt plain occurs further south of the catchment divide with only a relatively minor proportion occurring in the WCMA region. The main tributary is George Creek which flows north into Mount William Creek.

These plains of Quaternary and Neogene volcanics (Newer Volcanics) have scattered stony rises and basalt 'floaters' in pedologically young soils. Later alluvial and aeolian sediments often overlie these basalts where displaced drainage has redeveloped as internal drainage systems with swamps (Sibley 1967). Basalt flows may have thicknesses in excess of 150 m although large areas are generally less than 20 m (Cayley & Taylor 2001). Regolith has developed to several metres in depth of mottled red clay with pisoliths.

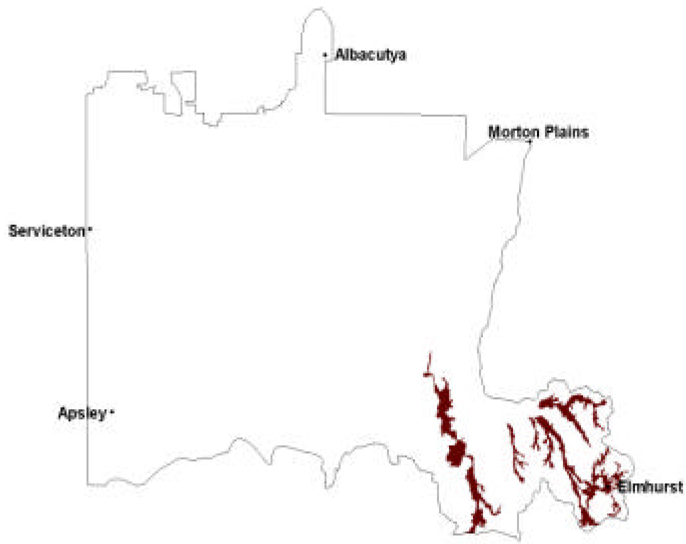
The basalt plains are known for their heavy clay soils that often result in surface ponding with many of these soils likely to have been Hydrosols prior to surface drainage. Cracking clays soils (Vertosols) with dark brown clay loam to heavy clay topsoils (slightly acidic) overlie massive bleached subsurface horizons with ferruginised nodules. A clear boundary exists to the brown to yellow brown heavy clay subsoil that is neutral to alkaline. In addition to cracking clays, sodic brown, yellow and grey texture contrast soils (Sodosols) are dominant with dark greyish brown clay loams overlying a conspicuously bleached horizon before an abrupt change to mottled heavy clay subsoils. Throughout ferromanganiferous concretions occur. Soils may have experienced varying amounts of aeolian sand into topsoils from arid palaeoenvironments.

Red Gum Wetlands of red gums (*Eucalyptus camaldulensis*) and swamp gums (primarily confined to swamps and poorly drained plains) are the only indigenous tree species on the basalt plains with sandy woodlands dominant on the fringes of these landscapes. Plains Grassland and Sedge Wetlands of wallaby, brome and kangaroo grasses are thought to be a natural sub-formation (Sibley 1967).

Swamps and alluvial plains are scattered across the basalt plains where a defined lateral stream has not yet developed (Cayley & Taylor 2001). These swampy wetlands are habitat refuges to many flora and faunal communities including brolgas.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Barton lava plains | Lava plain | 21 |

## 2.1.7 Terraces and floodplains (Mount Cole Creek, Mount William Creek)




Alluvial systems within the dissected uplands of the WCMA region include Mount Cole Creek, Mount William Creek and the Wimmera River. Mount Cole Creek, the upper Wimmera River and other minor tributaries are supplied surface and groundwaters by Palaeozoic bedrock hilly terrain and Neogene cappings that line many lower hillslopes. As a tributary that supplies the Wimmera River, Mount William Creek rises on the slopes of Mount. William in the Grampians Ranges and flows slowly to the north-west through Dadswells Bridge. Extensive alluvial plains of this drainage system represent a low pass (geocol) that separates the dissected uplands (Midlands) to the east from the Grampians Ranges to the west.

These fluviatile alluvial plains are characterised by their effluents and anabranches which leave the main channels (Sibley 1967). The tributaries are called subsequent streams where streams have evolved along areas of rock belt weakness leaving folded or titled strata of differing resistance as prominent strike ridges (Hills 1975). The drainage networks of Mount William Creek, Salt Creek, upper Wimmera River/Mount Cole Creek and Wattle Creek are aligned in a north-north-westerly alignment with strike ridges on a regular spacing of 10-15 km. Valley flats, terraces and flood out plains are common with Mount William Creek the broadest in cross tributary dimension (often in excess of 5 km) while others are typically less than 2 km. Slopes are gently to very gently inclined with terrace slopes of greatest inclination (up to 10%) found along Mount Cole Creek and the upper Wimmera River.

The entrenched valleys of Quaternary sediments including the Shepparton Formation (a thick sequence of unconsolidated fluvial and lacustrine sediments – coarse sand, silt and clay) occur largely as terraces, plains and drainage lines. Sediments have been derived through differential weathering of granite masses that are surrounded by ridges and peaks of resistant metamorphosed sediments. The Coonambidgal Formation (reworked Shepparton Formation of slightly micaceous silty clay, sand and gravel) occur within drainage lines subject to flooding and inset streams (Butler 1958; Krokowski de Vickerod, Moore & Cayle 1997).

Floodplains of Mount William Creek are lined by aeolian deposits (sands) sourced from the Grampians Ranges and lined by river red gums on the subdued slopes of this inset stream. The plains and terraces of the upper reaches of the Wimmera system around Mount Cole Creek, Concongella and Elmhurst have been formed by the more rapid weathering of granitic rocks in the area, accompanied by the deposition of recent alluvial sediments. Incipient weathering profiles of older fluvial deposits have some mottling reflecting poor site drainage and clay alleviation processes. Granitic detritus of these valley systems has high concentrations of quartzose sand intermixed with silts that often compose terraces occupying elevated positions above the current drainage plain.

Soils of the unit are deep grading into the generally unconsolidated regolith. These may range from texture contrast, generally sodic (Sodosols) to gradational earths and occasional clay (Vertosols, Dermosols) and sand soils (Tenosols). Some soils may be waterlogged prone for at least three months of the year (Hydrosols).

The texture contrast soils vary between the red non-sodic soils against the brown, yellow and grey sodic variants. All have sandy loam surfaces overlying a massive conspicuously bleached subsurface horizon. A clear change exists to light and medium clay subsoils where sodicity and colour are the distinguishing features. Importantly, the red texture contrast soils are commonly associated with terraces rather than current alluvial plains. Here most of the gradational yellow and brown soils (Kandosols) are found.

Remnant vegetation communities are dominated by forests (Heathy Dry Forest and Grassy Forest) closest to intersection of the Wimmera River downstream of Greens Creek where stream gradients are low and anabranching is well defined. Woodlands including Damp Sands Herb-rich Woodland, Plains Grassy Woodland, Creekline Grassy Woodland, Riparian Woodland, Plains Woodland, Grassy Woodland occur along Mount William Creek, with Lateritic Woodland, Sand Heathland, Sand Forest, Red Gum Wetland and Sedge Wetland found on floodplains and flats away from the current drainage depression.

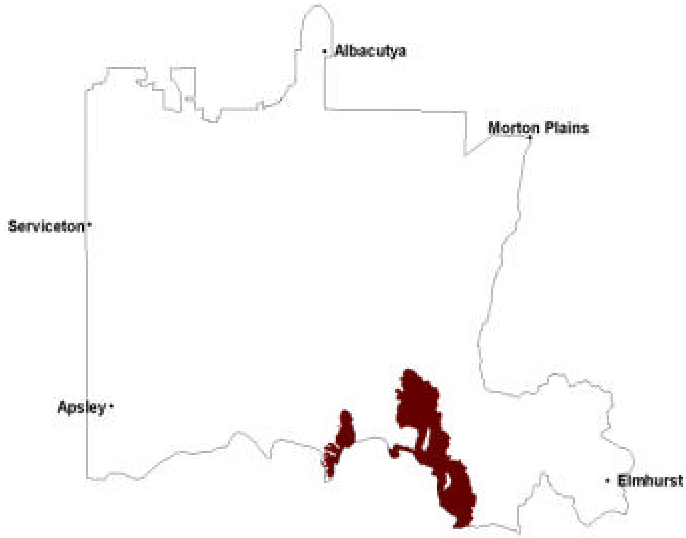
Heathy Dry Forest and Grassy Forest vegetation communities are associated with exposed areas of the alluvial plains of the upper Wimmera River and Mount Cole Creek while Herb-rich Foothill Forest and Valley Grassy Forest are more associated with the sheltered areas higher in the catchment. Various woodlands including Alluvial Terraces Herb-rich Woodland also occur across these valleys. Dry woodlands dominate the drainage of Six Mile Creek/Seven Mile Creek and Salt Creek.

The alluvial plains often compose later derived sediments that overlie gravels and sands of these valley deposits. Large volumes of groundwater are attributed to these alluvial systems through contributions of Grampians colluvium where rainfall is often twice that of the plains. Wetlands line Mount William Creek (especially north of Jallukar) to its integration with the Wimmera River. Lake Lonsdale and Lake Fyans represent large swamps that have now been dammed to form water supply dams for Stawell and Ararat.

Further east, Greens Swamp (includes a main swamp and shallow ephemeral wetland) has been derived from a small catchment that has been unable to breach the levee of the Wimmera River (Hocking 2004). This swamp has a large clay lunette that pre-dates major lake forming processes of the Murray Basin and reflects an intricate balance between climatic and groundwater conditions for lunette development.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Howard Creek plains | Dissected plains | 33 |
| Mount Cole Creek | Drainage complex | 204 |
| Mount William Creek 1 | Alluvial plain | 133 |
| Mount William Creek 2 | Alluvial plain | 106 |
| Six-Seven Mile creeks | Drainage complex | 68 |
| Wattle Creek covered plain | Covered plain | 73 |

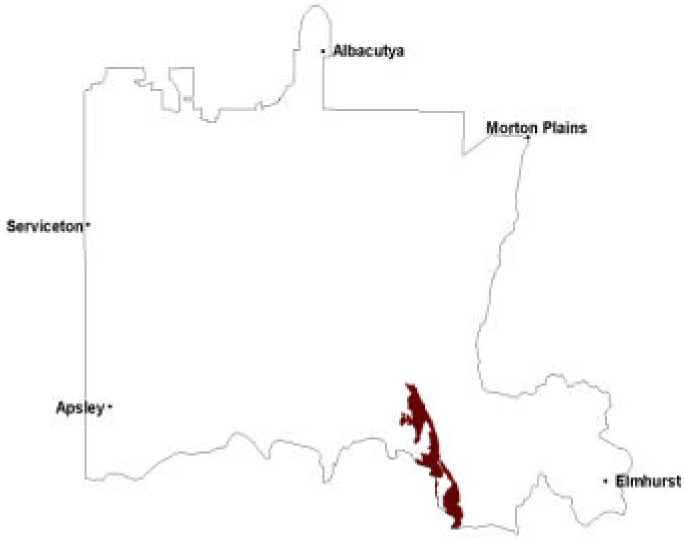
## 2.2 Strike ridges and valleys - Grampians Ranges




The strike ridges and valleys consist of a series of parallel ranges extending in a north-south orientation for nearly 90 kilometres (Sibley 1967). The ranges are characterised by striking cuesta-and-vale morphology with dipping sandstone beds to the west and scarp faces pointing to the east. The sandstones outcrop as three mountain ranges, Mount William Range in the east, Victoria Range to the west and various broken ranges in-between Mount Zero and Mount Sturgeon known as the Serra Range. These ranges are thought to have been derived through multiple repetitions (stacking) of three stratigraphic units along bedding parallel faults within siltstone (Cayley & Taylor 1998). The escarpments, steep slopes and sharp crests are in contrast to the rest of the Western Uplands which generally have rounded topography.

Major valleys and subsequent streams have developed along fault lines or less resistant siltstones and shales (Spencer-Jones 1965; Cayley & Taylor 1997; Hills 1975) with ranges interrupted by granitic intrusions in the Victoria Valley (negative relief granite) and at Mount William. A major structural monocline at Wartook Reservoir has resulted in dissection and displacement with the Mackenzie River occupying a synclinal valley towards Mount Difficult and Mount Victory (Hills 1975). Terraces and floodplains occupy valleys and are dominated by sourced material from sandstones and weathered granite.

## 2.2.1 Cuesta landscapes (Mount Difficult Range, Mount William Range)




The striking cuesta and vale topography of the Grampians Ranges occur within the western extents of the Midlands of Victoria. Extending from Mount William in the south to Mount Zero in the north, the Mount Difficult and Mount William ranges provide spectacular relief over surrounding landscapes of gentle to undulating topography that have defined drainage networks supplying the Wimmera River in the north.

The cuesta landscapes of the Grampians Ranges general height varies between 450 m and 1000 mAHD with significant peaks of the Mount William Range including Mount William (1167 m) and the Major Mitchell Plateau (over 1100 m). This series of strike ridge and valley terrain is repeated in a pattern running east-west that extends for over 40 km. Subsequent streams of these valley floors carry large volumes of water to reservoirs (Wartook Reservoir) and lakes from major tributaries including the MacKenzie River and Mount William Creek.

There are two small areas of plateaux where the sandstones have very low angle dips including Major Mitchell Plateau and an area above Zumsteins in the Mount Victory Range. At the northern end of the Mount William Range near Halls Gap the landform converts from cuesta landscape to form a series of hogbacks where sandstone beds dip with very high angles and steep ridges (Sibley 1967). Dip slopes in the cuesta landforms vary according to degree of fracturing/jointing and dissection that are reflected in vegetation and faunal relationships (Sibley 1967). Slope classes defined include dissected dip slopes (sandstone strata fractured and dissected with steep buttresses separated by chasms e.g. Wonderland Range), smooth dip slope (extensive areas of bare dipping rock e.g. Elephants Hide) and colluvial dip slopes (smooth dip slopes that are unbroken with scree material common e.g. Miranatwa).

The Grampians Group (Spencer Jones 1965) comprises a rock sequence with a stratigraphic succession of quartzo-feldspathic to micaceous sandstone overlain by a micaceous mudstone and finally a quartzose sandstone package (Cayley & Taylor 2001). Latest interpretation of these sedimentary stacks has a number of thrust faults that have intersected this sequence and juxtaposed the stratigraphy in a repetition of strike ridges and valleys through differential erosion. Formed during the late Ordovician to early Silurian, the sediments of the ranges belong to the Red Man Bluff Subgroup and Mount Difficult Subgroup with a cumulative stratigraphic thickness of 3700 m.

Narrow intermontane valleys with subsequent streams occur between the classical cuesta landform patterns of the strike ridges that host significant deposits of colluviium and alluvium from dip slopes and scarps. Jointing and faulting has resulted in significant dissection of the stratigraphic sequence controlling stream pattern density across and along slopes. Stream pattern drainage of the tributaries is pinnate in nature with steep slopes supporting major stream courses running perpendicular to dip slopes. Easterly facing cliffs and steep slopes, along with westerly dipping rock slopes have thin to non-existent regolith and soil development that are sandy. Flat to gently sloping topography has been found with pronounced weathering profiles. The Major Mitchell Plateau and Mount William are possibly the only remnants of the once extensive Mesozoic palaeosurface (Hills 1975; Cayley & Taylor 1997). The ranges are likely to have been exposed in early Cainozoic times as a series of arcuate ridges with the topography more pronounced with further dissection and erosion of less resistant beds of the repeated sedimentary stack.

With the high proportion of rock outcrop, fresh and shallow soils (Rudosols) are common with sandy soils (Tenosols, Kandosols) occurring on mid to lower slopes and texture contrast soils, often acidic on the lower slopes (Kurosols), where there is some clay accumulation in the subsoil. All soils have high concentrations of coarse and fine sand that have extremely high rates of infiltration and allow rapid drainage.

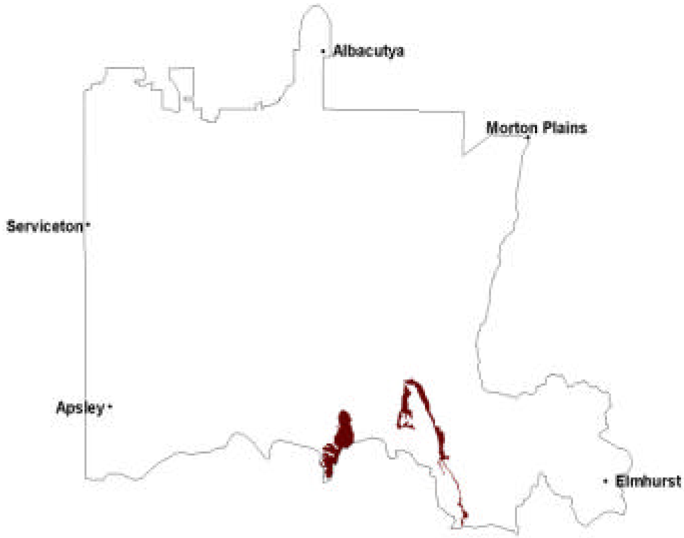
A number of woodland, forest, shrubland and heathland vegetation communities have been recorded including Lowland Forest, Heathy Dry Forest, Rocky Outcrop Shrubland, Heathy Woodland, Rocky outcrop Shrubland/Rocky Outcrop Herbland Mosaic, Shallow Sands Woodland and Sedgy Riparian Woodland. Native vegetation is well preserved within these landscapes with wet and dry sclerophyll forests dominated by brown stringybark (*Eucalyptus baxteri*), messmate (*Eucalyptus obliqua*), long leaf box (*Eucalyptus goniocaylx*) and heath understorey.

Fire is a rather unique feature that has been common throughout the European settlement of the ranges as well as in pre-European times when the Jardwadjali tribe occupied these ranges. Erosional events often occur post fire events where understorey is removed leaving vulnerable sandy topsoils exposed to extreme rainfall events and significant wind from the south and west. Landslip scars on the south facing scarp of the Mount Difficult Range near Halls Gap also highlight failures of shallow soils that have been saturated. Rock falls are extremely infrequent and are mainly confined to scarps and cliffs of south and easterly facing rock exposures.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Grampians Ranges | Mountains | 291 |

Figure 7 Wartook syncline from the northern end of the Grampians Ranges

## 2.2.2 Sandstone hills (Black Range)




The western Black Range lies to the west of the Grampians Ranges and consists of dipping sandstone beds of the Grampians Group sediments. Occurring on the WCMA southern catchment boundary, the ranges play a vital role in supplying pristine water to the reservoirs and lakes of the Wimmera and Glenelg-Hopkins regions.

As a cuesta landform, the massive beds of quartzose sandstones are extremely resistant to weathering giving significant relief to this range over surrounding plains and sandsheets. Mount Byron (over 500 m) and Mount Talbot (over 300 m) remain as two significant peaks within the structurally controlled sedimentary stack of the western Black Range.

Slopes of the range are generally gently inclined with steeper slopes, scarps and cliffs found on the eastern exposures of the range.

The Black Range is a structural repeat of the Grampians Group (Spencer Jones 1965) comprising sandstone and a micaceous mudstone overlain by quartzose sandstone (Cayley & Taylor 2001). Sedimentary structures, including large-scale aeolian dune cross-bedding in the Daahl Sandstone, are prominent in scarps and exposures of these landforms.

Drainage is divided between a short radial network of tributaries (Mochong Creek, Holligan Creek and Matthew Creek) that deliver surface waters to Rocklands Reservoir and creeks that feed the Toolondo Channel and Norton Creek to the north-west. Alluvial deposits are located along many of these defined drainage courses with significant colluvial deposits found on the eastern margin of the strike scarps as well as long westerly dipping rock slopes. Plateau areas support deeper regolith profiles than scarps and steep slopes.

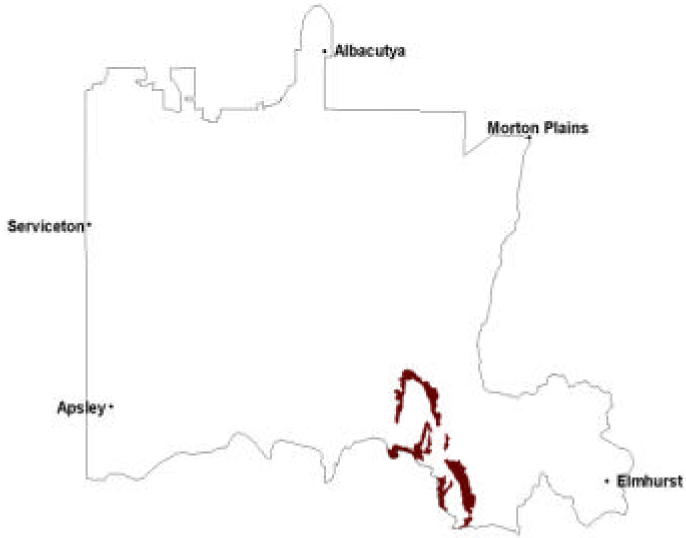
Similar soils to the Grampians Ranges occur with the major soils including sandy soils with pans and acidic, grey texture contrast soils with sandy surfaces. Here soils tend to be deeper than those developed on steeper landscapes.

The sandy soils with pans (Tenosols and Podosols) comprise organic rich surface sands over a conspicuously bleached subsurface horizon. A further change occurs where a yellow organic and sesquioxide discontinuous pan (coffee rock) sits over mottled clay further down the profile. Grey texture contrast soils (Kurosols) have sandy surfaces with yellow and red mottled light grey clay loams to medium clay. Both soils have an acidic profile trend with the texture contrast soils strongly acidic.

A number of woodland, forest, shrubland and heathland vegetation communities have been recorded within the Black Ranges. Rocky outcrop Shrubland and Rocky Outcrop Herbland are associated with scarps and bedrock exposures while woodlands and forests are located on exposed western slopes or sheltered eastern slopes. Dry sclerophyll forests with brown stringybark (*Eucalyptus baxteri*), long leaf box (*Eucalyptus goniocaylx*), occasional messmate (*Eucalyptus obliqua*) in wetter areas, and heath understorey.

| Soil-landform unit | Unit description | Area (km$^2$) |
|---|---|---|
| Grampians outwash slopes | Outwash slopes | 134 |
| Grampians Ranges | Hills | 112 |
| Quantong dune and swales | Dune and swale | 1 |

## 2.2.3 Valleys, alluvial terraces and floodplains (Halls Gap)




Extensive and broad zones of outwash sands surround the prominent strike ridges of the Grampian Ranges. Examples include outwash slopes along the eastern fringe of the Grampians Ranges, for example, the Pomonal area, western Black Range and Fyans Creek Valley.

These depositional landscapes are dominated by landforms including alluvial fans, sand plains and tributaries of major drainage networks within and surrounding the ranges (e.g. Mount William Creek, Wannon River, and Glenelg River). Outwash slopes of sandsheets have maximum gradients of 5% that tend to level out towards alluvial flats and drainage lines below the ranges. Relief is generally 30 m or less (Ollier & Joyce 1986) over long gentle slopes with the number of depositional layers and depth of these deposits varied. Terraces and floodplains are found along valleys within the confines of the Grampians Ranges (Hills 1936).

Streams are unidirectional flowing away from the prominent strike ridges of the Grampians and Black ranges, often converging as tributaries into significant waterways of the catchment as creeks and rivers of floodplains and alluvial plains. Lake Belfield in the Fyans Creek Valley is an example of a dam that has harnessed the significant volumes of water shed by the ranges and slopes into this significant water supply.

Sandy deposits of these colluvial valleys, alluvial terraces and floodplains are often quite deep and extensive, overlying deeply weathered members of the Grampians Group. Deposits are typically composed of sandstone pebbles in a matrix of sand or clay. Colluvial fans surrounding the Grampians Ranges are thick (20–50 m in places) with some of the deposits no longer active due to the regulation of stream flows and development of Lake Belfield. The alluvial fan debouching from Halls Gap is an example of this where sands, silts and clays form a thin veneer (Cayley & Taylor 2001). High concentrations of organic matter are prevalent especially in the Fyans Creek Valley where high rainfall combined with low exposure to northerly and westerly winds preserves moist environments responsible for these deposits.

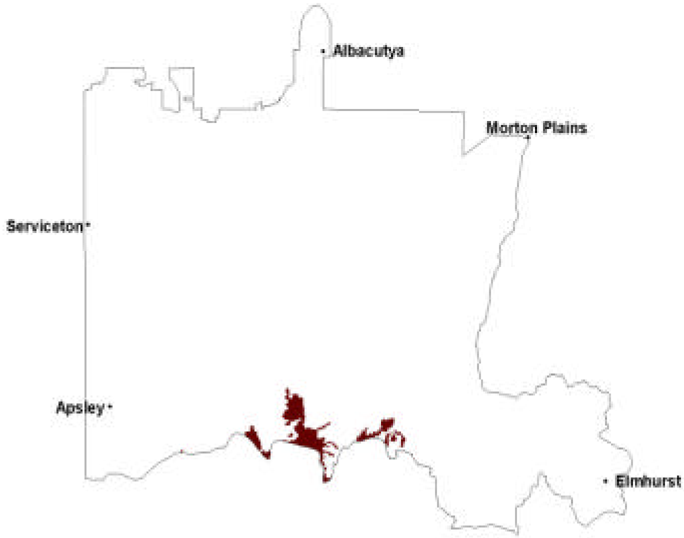
Sands are prominent throughout soils of these landforms with brown and yellow texture contrast soils common. Profiles with deep sands (Podosols, Kandosols) or without pans (Tenosols) also occur along with cracking clays (Vertosols) in lower depressions.

The texture contrast soils occur with sandy topsoil over strongly mottled clayey subsoil which may be slightly acidic (Kurosols) or occasionally sodic (Sodosols). Depth of these profiles is generally greater than 100 cm.

Vegetation is typically sandy to wet heathlands/woodlands and short dry sclerophyll forest (Heathy Dry Forest) that intermingle on outwash slopes, with woodlands predominating on the wetter middle and lower positions and forests on drier upper positions (Sibley 1967). Messmate, brown stringybark, apple box and peppermint are common, with long leaf box found occasionally on the uppermost slopes. Heathy understorey occurs in scattered areas where waterlogging is evident.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Grampians plains | Colluvial outwash slopes | 311 |

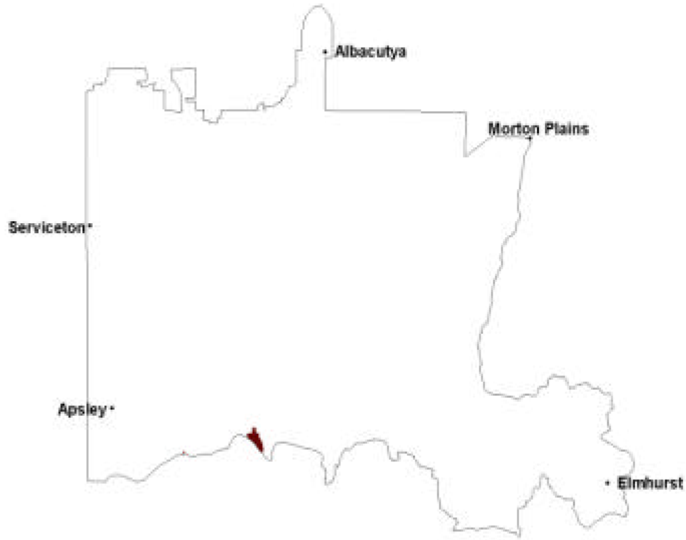
## 2.3 Low elevation plateaux (tablelands)




Beyond the Grampians Ranges, low plateaux or tablelands are characterised by deep lateritic weathered profiles. These are developed over a range of rock types probably in part on a transported cover of Cainozoic age. The domal topography, active stream erosion and evidence of uplifted and deformed Neogene shoreline ridges indicate neotectonic activity. The characteristic (altered from pre-European) vegetation is scattered red gum woodland.

These tablelands abut the Grampians Ranges forming an apron, mainly to the west. They are differentiated by the degree of dissection, but are also characterised by the underlying geologies such as acid volcanics and a range of geologies including granite, basalt, metasediments and Permian glacial deposits. These constitute the two divisions of the Dundas Tableland, while the heavily dissected Merino Tableland lies to the south on Cretaceous sediments within the Glenelg Hopkins CMA region.

## 2.3.1 High relief, low drainage density (Western Dundas Tableland – Harrow)




Sections of the Western Dundas Tableland occur in the WCMA region along the south-western boundary of the catchment (e.g. Kadnook). Fault scarps and a monocline (Kanawinka Monocline) towards the South Australian border delineate the western extent of the Dundas Tableland.

Importantly, these occurrences within the WCMA region occur on the northern margin of the Glenelg River and reflect the extreme dissection of the tableland. Sandy rises and plains of the stranded beach ridges along with the Douglas Depression neighbour these artefacts of a once much larger peneplain that may have extended across much of Western Victoria including the upper Wimmera catchment.

The western block of the Dundas Tableland (elevation at 320-360 m (Quinn 1977)) comprises an elevated low plateau that resulted from domal uplift of underlying Palaeozoic and Mesozoic rocks that are largely obscured by overlying Cainozoic deposits. Uplift in the Neogene and sea-level falls during the Quaternary (Joyce 1992) resulted in incision of the main rivers (Glenelg and Wannon) forming deep narrow valleys. This deep incision and dissection of the peneplain coupled with domal warping allows distinction of the western Dundas Tableland against its eastern block.

Slopes are gentle to very gentle with little significant relief across the landscape, however majestic red gum occupy slopes and plains along with groundwater discharge in lower topographic reaches are extremely prominent features of this landscape. Surface drainage into the Douglas Depression is through a series of dendritic stream systems that supply White Lake and Centre Lake in the south of the depression.

Intense weathering during the Palaeogene and Neogene has resulted in deep regolith profiles that are characterised by basal kaolinitic saprolite with strong cementation of ferromanganiferous nodules (ferricrete) in the upper profile. The blanketing of the underlying bedrock with deep regolith is known as the Dundas Surface (Hills 1939, 1975).

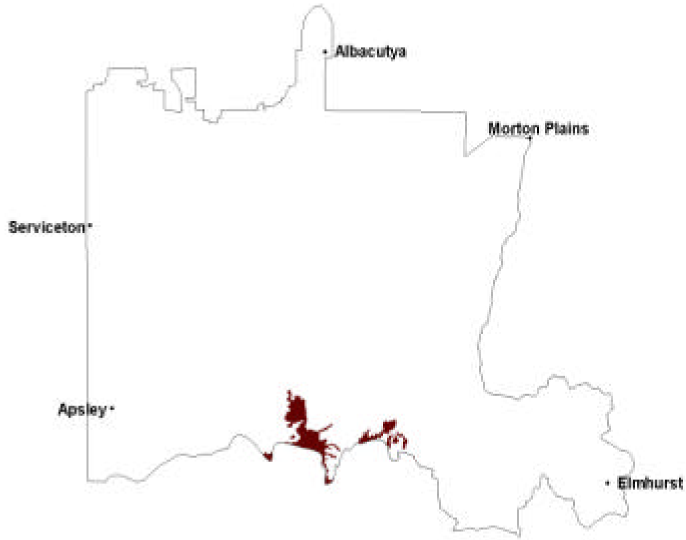
The Cainozoic duricrust of the Dundas Tableland represents the product of weathering from late Palaeogene times to present. The ferruginisation of strandlines left behind during the Pliocene regression lies above a surface that has experienced isovolumetric alteration, preserving original rock structures (Joyce et al. 2003). Slightly weathered to fresh bedrock degrades into a weathering surface with an alteration rind common along joints and fractures. A pallid zone of completely decomposed bedrock with bedrock features is preserved in white kaolinite formed from the oxidising and reducing conditions of watertable fluctuations (Paine 1995). Completely weathered fractured rock with iron enriched cores then graduate into the upper mottled zone with prominent 'tiger mottles' of enriched iron layers alternating with iron depleted clays in a lateral sequence. Sandy loams with variable quantities of ferromanganiferous nodules highlight surface sequences of this prominent regolith sequence.

Soils are gradational to texture contrast soils with sandy surfaces and heavy subsoils (Dermosols, Chromosols). With acidic profile trends, ferricrete and ferruginous segregations (buckshot) are common features of once larger palaeosurface. The distinctive red and pale grey mottling of subsoils is recognised as 'tiger mottling' and is a feature found across the tableland in these texture contrast soils.

Vegetation of these undulating to steeper slopes is largely savannah woodlands (Heathy woodlands) with remnant red gum scattered across the peneplain and concentrated along drainage lines within deep valleys. Plains Sedgy Woodland, Seasonally Inundated Shrubby Woodland and Shallow Sands Woodland occur on poorly drained soils.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Harrow valley | Deeply dissected valley | 26 |

## 2.3.2 Low relief, low drainage density (Eastern Dundas Tableland – Brimpaen)




Occurrences of the Eastern Dundas Tableland within the WCMA region include plains between Cherrypool and Brimpaen along with gently undulating plains at Telangatuk East. The plains fall either side of the western Black Range and as such represent part of a once expansive Neogene plain.

The eastern part of the Dundas Tableland is an undulating to rolling landscape of plains and rises underlain by Palaeozoic and Mesozoic rocks including Rocklands Rhyolite. Neogene deposits of Parilla Sand are superimposed over these older rocks while more recent fluvial deposits mask most of the plains. These plains and rises differ significantly from the Western Dundas Tableland due to the relative low relief of the landscape and lower drainage density as well as the limited incision and dissection within the landscape. Slopes are level to gently inclined depending upon position in the landscape. Plains and rises extend southwards to form part of the greater Dundas Tableland.

Overlying Cainozoic deposits are noted for their deep regolith profiles with kaolinitic saprolite and strong cementation of ferromanganiferous nodules (ferricrete) in the upper profile resulting in texture contrast soils. Stream incision of the peneplain is not as severe as the Western Dundas Tableland with slopes for gentle and valleys rolling rather than entrenched as on the Western Dundas Tableland.

Vegetation of these slightly undulating slopes is largely savannah woodlands with red gums scattered throughout the landscape.

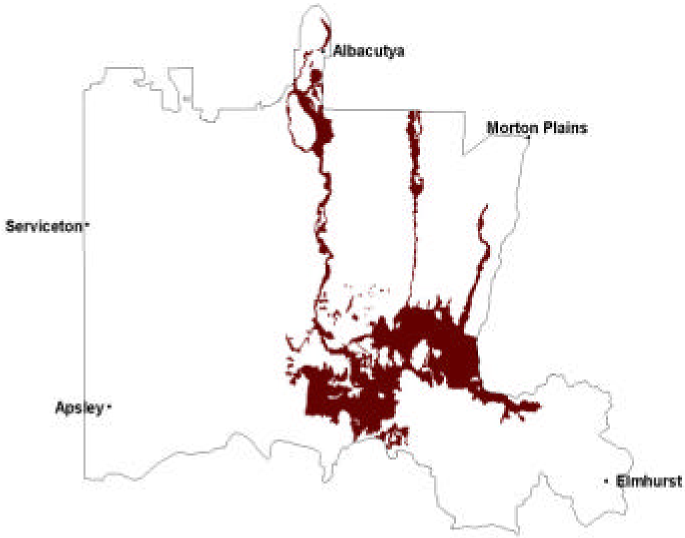
Soils are similar to those on the high relief low density tableland (2.3.1) being gradational through to texture contrast soils with sandy surfaces and heavy subsoils (Dermosols, Chromosols). Ferricrete and ferruginous segregations (buckshot) are common as is the distinctive red and pale grey ‘tiger mottling’ that is representative of these Neogene regolith profiles. Grey (occasionally brown and black) cracking clays (Vertosols) may also occur in the depressions and on level plains.

Wetlands of these plains that also supply water to the Rocklands Reservoir occur south of Brimpaen. Savannah wetlands that are subject to periodic waterlogging seasonally provide habitats to many forms of fauna. Salinity is also a major issue (where exposed in drainage depressions often as discharge sites) with highly acidic conditions resulting in precipitation of acid sulphate minerals.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Balmoral undulating plain | Deeply dissected valley | 32 |
| Brimpaen undulating plain | Undulating plain | 56 |
| Grampians outwash slopes | Lower outwash slopes | 14 |
| Telangatuk plains | Flat plain | 132 |

# 4 Northern Riverine Plains

On the Riverine Plain of northern Victoria, many parallel streams head north across a strikingly flat plain to meet the current course of the River Murray. Initially the pattern would have been difficult to visualise, but with long, detailed mapping of soils and landforms by workers such as Butler(1950, 1956, 1958), Pels (1964, 1966, 1971), Bowler (1976), Lawrence (1966, 1972, 1975) and Macumber (1972, 1983, 1991), a clear picture emerged, to be confirmed by later mapping using aerial photographs and satellite imagery. Studies of groundwater and salinity, and recent dating by luminescence, have also helped provided a better understanding of landscape evolution.




The WCMA region encompasses part of the Riverine Plain of New South Wales and Victoria; a very extensive and complex alluvial plain associated with the River Murray and its tributaries. It developed following the retreat of the Pliocene sea from the Murray Basin. In Victoria, the Riverine Plain extends northwards from the Western and Eastern Uplands to the River Murray; to the west of the state where it meets the North West Dunefields and Plains. The climate of the Northern Riverine Plains is semi-arid in the north-west and subhumid in the east and south-east. Most of the area originally carried eucalypt woodlands with occurrences of casuarinas, but there were substantial areas of treeless plain. Changing climate, vegetation, runoff and evaporation during the Quaternary have produced palaeochannels of different ages.

The Riverine Plain can be divided into an area fringing the uplands, with modern and palaeostream channels crossed by modern river channels such as the Yarriambiack Creek and Dunnmunkle Creek. The sediment of these rivers has been mapped as the Coonambidgal Formation by Lawrence and Abele (1988) and carries young dark shallow organic soils. Source-bordering dunes are found along these older channels, generally on their north-eastern sides.

The Riverine Plain consists essentially of two geological formations. The older is the Shepparton Formation of Pleistocene age, and the younger is the Coonambidgal Formation of late Pleistocene to Holocene age. On the more elevated parts of the main plain is an older series of small, meandering, leveed stream channels, which died out as tributaries away from their uplands source. Much of the Riverine Plain is made up of these older alluvial plains, which form broad fans extending and widening northwards from the uplands edge. Their alluvium, mapped as the Quaternary Shepparton Formation by Lawrence (1966), is covered by red-brown texture-contrast soils with subsoil carbonate. Largely inactive leveed channels of several ages are present, in places forming ridges above the general level of the plains (e.g. Wal Wal, Corkers). These stream channels were formerly referred to as prior streams (Butler 1950).

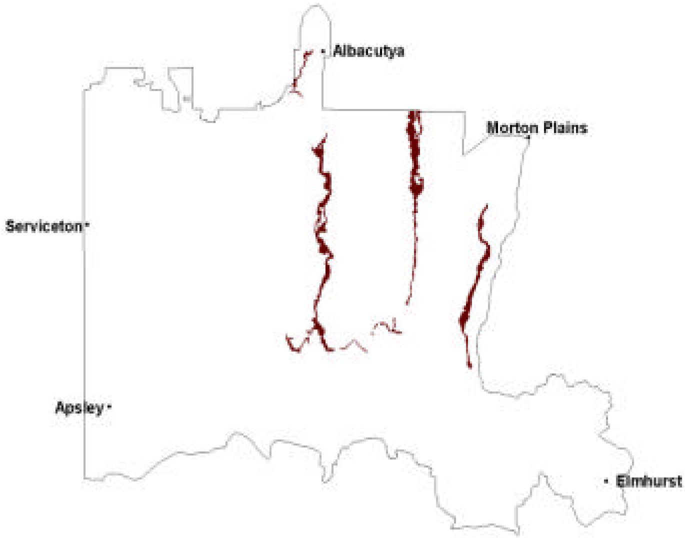
Channel deposits of Late Pleistocene and Holocene rivers and floodplain sediments comprise the Coonambidgal Formation of the Wunghnu Group (Lawrence 1966; see also Butler 1958). Modern rivers have been termed Coonambidgal IV, the youngest of a sequence of four alluvial terraces (Pels 1964 1966, 1971). On the Riverine Plain these features are typically inset within elevated alluvial terraces of the Shepparton Formation (Pels 1964).

Also included within the Riverine Plain for the WCMA region are alluvial fans and aprons (4.3) and lakes and basins with lunettes (4.2.3). Higher terraces, alluvial fans and aprons of uncertain age occur along the edge of the uplands, for example along the Mackenzie River and north and east of the Grampian Ranges.

Many of the present lakes in the Murray Basin are ephemeral or relict features, evidence of much more efficient hydrological regimes during the Middle and Late Pleistocene. Most are now either permanently dry or episodically filled by floodwaters. Lakes are recognisable by their depressed planar beds, cliffed western margins and source-bordering dunes to their east (Bowler & Magee 1978). They are typically elliptical or reniform in shape and are connected to river systems by inlet channels. Swamps and claypans usually occupy low-lying areas, such as palaeochannels, relict groundwater discharge features and dune swales. They intermittently retain surface water from runoff after rain. Concentrations of lake and lunette systems are found around Lakes Hindmarsh and Albacutya. Tectonic movement and geological lines of control (faults and folds) have influenced the formation of the lakes and the associated streams (direction/orientation).

The different landforms combined with different regolithic material has produced a range of soils from waterlogged prone soils (Hydrosols) to texture contrast soils, generally sodic (Sodosols), cracking clay soils (Vertosols) and calcareous soils (Calcarosols) found in the drier ares and often on lunettes. Vegetation types are also influenced by these factors (e.g. black box can be found in the depressions, and yellow box and yellow gum on the better drained areas).

## 4.1 Modern floodplains (Coonambidgal Formation)




The Modern floodplains are closely associated with the Wimmera River and its effluent streams including Yarriambiack, Dunnmunkle and Two Mile creeks. All flow north, first across Older alluvial plains and then, in the case of the Yarriambiack and Dunnmunkle creeks, across the clay plains with subdued ridges (unit 5.4) north of the Wimmera Trench. Under flood conditions Two Mile Creek flows into Darlot Swamp. A tributary to the south of Horsham, the Mackenzie River, flows north across an extensive alluvial apron (unit 4.3) and joins the Wimmera River between Horsham and Quantong.

North of Darlot Swamp in the clay plains, the current course of the Yarriambiack Creek appears to have been structurally determined by the close proximity of the stranded beach ridges on either side of the creek. Depths of valley floors beneath their adjacent geomorphic units vary between streams and along the lengths of individual streams.

In addition to erosion-deposition cycles with discharge flow variation, faulting may also have played a part in valley depth variation as there is a possible east-west fault just north of Darlot Swamp. The resultant slow relative rise of the clay plains block to the north may have contributed to the increasingly shallow Yarriambiack Creek Valley from Jung 40 km towards Warracknabeal. In the Quantong area relatively recent and higher Wimmera River flows have resulted in a complex array of terraces and erosion gullies.

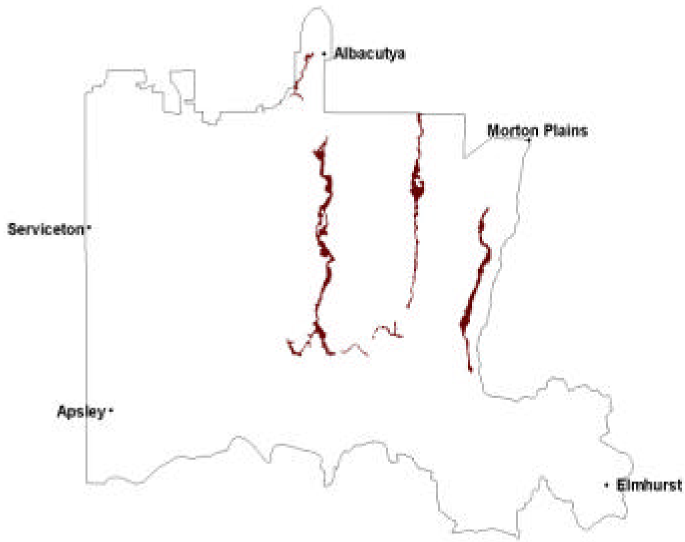
Two soil-landform units have been identified and mapped within this geomorphic division. The major one is the Wimmera River (originally referred to as the river frontage landscape) with the second more spatially restricted unit being the Yarriambiack and Dunnmunkle creeks (originally referred to as the valley floor landscape). This unit comprises the terraces and flats along that creek north of the Darlot Swamp.

Materials deposited during the late Pleistocene-Recent (collectively referred to as the Coonambidgal Formation) are source to a variety of soils including those with uniform texture profiles (massive grey Vertosols) and those with texture contrast profiles (grey Sodosols). These soils have been mapped as part of earlier surveys (high and low intensity) into a suite of soil types and soil associations including Murtoa Clay, Haven sandy loam and the Callawadda Association for example.

Some areas of native vegetation still remain with black box the dominant tree species occurring alone and in fairly dense stands. Vegetation communities along these floodplains include a variety of woodland, mallee and shrubland vegetation.

Liability to flooding, uneven land surfaces and the isolation of flats and terraces which make access difficult pose major hazards for the use of these floodplains for agricultural enterprises. The soil types occur in complexes making management with regard to specific soils particularly difficult. Soil types have variable recommendations for irrigated perennial pasture production due to their landscape position and their liable nature to flooding or to isolation by flooding.

## 4.1.1 Meander belt below plain level, sometimes source-bordering dunes (Wimmera River, Yarriambiack Creek)




This grouping of geomorphological units describes the (generally) youngest spatial landscape feature; the current floodplain of major streams. These units are generally incised into an alluvial plain (unit 4.2) with or without terraces. They are defined as un-confined due to an absence of surrounding uplands, their formation from alluvial material (Coonambidgal Formation), or that they comprise the most recent alluvial landform complex of the WCMA region.

The Wimmera River floodplain is the major unit with a number of effluent streams with confined floodplains such as Yarriambiack Creek and Dunnmunkle Creek. The floodplain is more obviously unconfined downstream of Glenorchy and has diverted north-west adjacent to Grampians outwash material (unit 4.3), then aligned east-west before sharply turning north and being confined within the Lowan Salt Valley and masked by the Little Desert (unit 5.2) just south of Dimboola. The floodplain terminates at Lake Hindmarsh where it is surrounded by predominantly calcareous plains and dunes. A channel with minor floodplain connects Lake Hindmarsh to Lake Albacutya. This floodplain is minor and intermittent amongst the calcareous dunes and plains (unit 5.1) and the siliceous dunes and plains of the Big Desert (unit 5.2). There are some other meanders in the mid Wimmera tract, particularly where tributary streams such as Mount William Creek confluence. Drainage across the plains varies from annabranching streams to meandering channels in form, with slopes very gently to gently inclined. Soil-landform units are relatively slender (generally less than 2 km across) and contain the entirety of the Wimmera River and Yarriambiack Creek within its extent.

Soils vary on the young unconsolidated regolith from sands to loams and clays where finer material has accumulated. There is a higher alkaline component (sodium and calcium) north of Quantong. Major soils include sodic, grey texture contrast soils (grey Sodosols) and cracking clay soils (Vertosols).

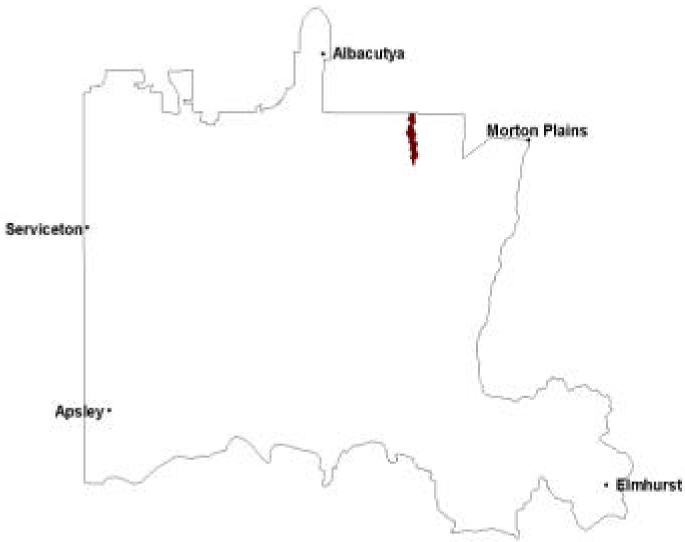
The texture contrast soils have slightly acidic sandy clay loam surfaces over grey light clays that increase in sodicity with depth. Minor carbonate occurs in the subsoil. The cracking clays are acidic at the surface with light clays clearly changing to heavy clay subsoils that can be more acidic at depth with very few carbonate nodules. Depths for all soils are generally in excess of 2 m.

Vegetation may also change with climate (drier to the north) though red gums are a major overstorey species. Vegetation communities along these floodplains include a variety of woodlands including Plains Woodland, Drainage-line Woodland, Salt Paperbark Woodland, Lignum Swampy Woodland, Riparian Woodland, Creekline Sedgy Woodland and Riverine Chenopod Woodland for example.

Flooding provides a significant hazard for this unit especially in urban areas along the rivers and creeks. Shrink-swell behaviour of cracking clays around these urban areas may also be a relevant factor in residential development and selection of footings that will accommodate clay expansion and contraction.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Wimmera River | River | 197 |
| Yarriambiack/Dunnmunkle Creek | River | 173 |

## 4.1.2 Areas of inundation away from modern channels (Yarriambiack Creek)




Extensive meander belts and source-bordering dunes that occur in a broad swale north of Warracknabeal note a former course of the Yarriambiack River. These younger incised channels were formerly referred to as ancestral rivers (Pels 1964).

Soils vary on these plains where a regolith consisting of sands, loams and clays has accumulated. The major soils include sodic, grey texture contrast soils (grey Sodosols) and cracking clay soils (Vertosols).

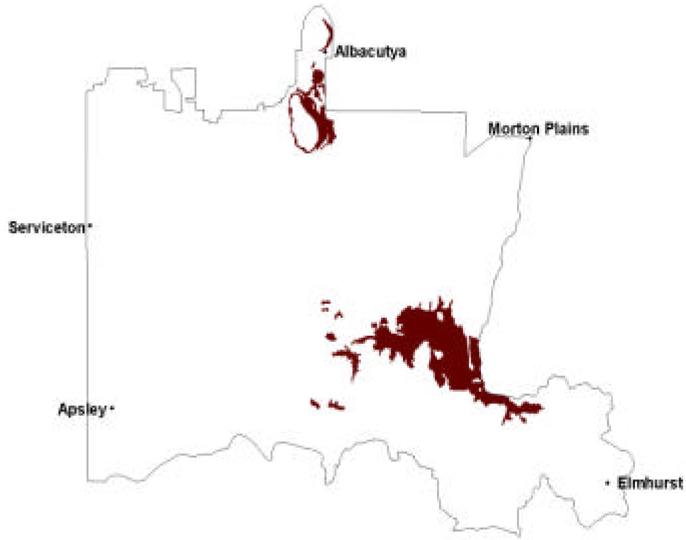
The texture contrast soils have slightly acidic sandy clay loam surfaces over grey light clays that increase in sodicity with depth. Minor carbonate occurs in the subsoil. The cracking clays are acidic at the surface with light clays clearly changing to heavy clay subsoils that can be more acidic at depth and with very few carbonate nodules. Depths for all soils are generally in excess of 2 m.

Vegetation is dominated by red gums as the major overstorey species. Vegetation communities along these floodplains include a variety of woodlands including Plains Woodland and Drainage-line Woodland.

Flooding provides a hazard for this unit but usually only after the modern channels have flooded.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Yarriambiack/Dunnmunkle Creek | River | 48 |

## 4.2 Older alluvial plains (Shepparton Formation)




Relatively level floodplains occur south of the Wimmera River between Horsham and Quantong and on both sides of the river east and south-east of Horsham. To the west of Horsham these plains give way to the grey clay plains and plain and ridge terrain as the Wimmera River alters course dramatically from west to north. These plains are extensive, occurring partly up Yarriambiack Creek and on both sides of Dunnmunkle Creek up to its junction with the Wimmera River near Glenorchy. In years of relatively high rainfall, extensive flooding may occur on both sides of the Wimmera River mainly between Horsham and Glenorchy. There is no obvious current floodplain of the Wimmera River in this broad plain which is about 5 km wide near Glenorchy. The plains extend out from the Western Uplands (units 2.1 and 2.2) to the east (associated with the Avon-Richardson drainage system) and south. Also to the south are alluvial aprons (unit 4.3) which may mask a subdued tableland (unit 2.3). The grey clay plains lie to the north and a string of discontinuous low rises/ridges or eroded apron material lies in a north-west/south-east axis near Lubeck. There are also a number of lakes and swamps associated with this broad unit (4.2.3).

The plains may be further separated at the geomorphological third tier level (units 4.2.1 and 4.2.2) on the basis of channel features and stream patterns together with associated differences in soil distribution patterns. Both older alluvial floodplain units together occupy the greater part of the Wimmera Trench. The plains are extensive and generally flat with minor level differences where intense soil and regolith investigation is required to differentiate behaviour changes in the landscape to water movement and other characteristics. There is very little dissection of this unit, apart from the main streams with a modern floodplain associated with Yarriambiack Creek.

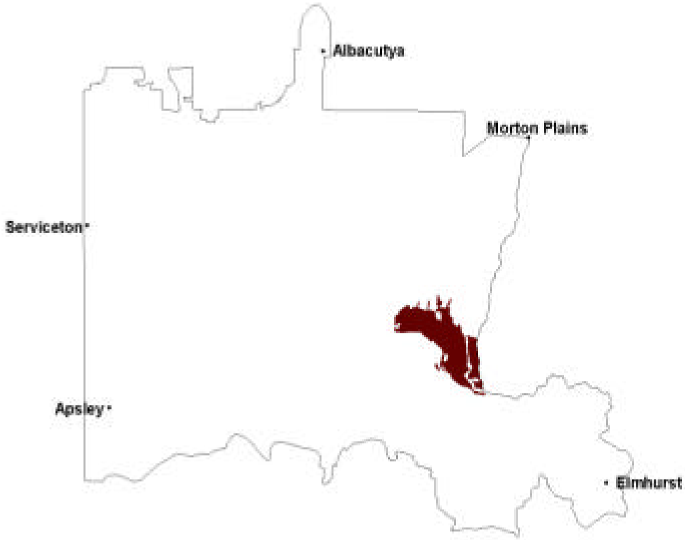
The soils of these plains have developed on materials deposited mainly during the Pleistocene. These sediments are collectively referred to as the Shepparton Formation. An extensive sand plain representing the Barrabool sand plains soil-landform unit (formerly referred to as the sand plain landscape) occurs south of Murtoa and occupies part of the Barrabool State Forest. The age of the regolith, its constituent particle size distribution and climatic factors have influenced the landforming processes and the pedological development of today's soil. As well as extensive alluvial sediments, aeolian clays and sand have also been incorporated.

Drainage systems are very sparse (apart from the major streams) but are more evident radiating off occasional gentle low rises. Local variations in drainage reflect spatial variation of soil and regolith types.

Grey cracking clay soils (Vertosols) and red and brown sodic texture contrast soils (Sodosols) are the major broad soil types formed on the alluvial, fine to coarsely textured regolith. There are a number of soil types and features such as the structure of the surface and self-mulching qualities making a significant difference in terms of production and land management. These are differentiated in the third tier units, where it is shown that there is greater soil type variation in the prior stream (with leveed channels) unit compared with the plains without leveed channels.

Waterlogging is an issue on these units due to the level or very gentle terrain and the soil or regolith type which is dominated by fine textured material for much of the area. Sodicity and structure decline are also issues resulting in reduced surface infiltration. Minor salinity may occur in local depressions.

### 4.2.1 Plains with leveed channels, sometimes source-bordering dunes (Wal Wal, Murtoa, Corkers)




Plains with leveed channels occupy much of the land between Glenorchy, Murtoa and Horsham. These prior stream plains comprise a suite of sand plains, floodplains and flats including the Corkers prior stream plains, Barrabool sand plains and Wal Wal prior stream plains soil-landform units. To the south lies the current course of the Wimmera River while to the north, the clays plains with subdued ridges are elevated above these plains.

Two prominent landform sub-patterns may be distinguished within the unit in the Horsham-Murtoa area. In the first one the best examples of leveed channels are those bordering the unnamed prior stream which runs from near the racecourse area on the Longrenong-Murtoa Road north–west towards Darlot Swamp. A second partly tree lined east-west water course runs parallel to, and just north of, the Longrenong-Murtoa Road to a low-lying area just south-east of the Longrenong College.

The second and minor subpattern is made up of a series of smaller near linear drainage lines which run on both sides of and parallel to this water course. In the area between Longrenong and Murtoa, the array of watercourses and drainage lines form a near divergent, from north-west to west, channel network comprising an anastomotic landform pattern.

Slopes of these plains are gentle in nature with slightly steeper slopes occurring where abutting slopes that lead to clay plains of the north. Soil-landform units are clustered together in areas dominated by the former Murtoa Soldier Settlement (today is part of the Wimmera Irrigation Area). Sediments are Shepparton Formation to Coonambidgal Formation in origin with extensive flooding events leaving a veneer of finer silts and sands deposited within existing prior stream levees and channels.

The channel network is reflected in the soil pattern. Within the Wimmera Trench this area has the greatest soil complexity in the number of classified soil types and particularly in their distribution. Six soil types representing self-mulching, epipedal and massive grey Vertosols, red Vertosols, and red and brown Sodosols occur in the unit. In terms of area occupied, grey Vertosols are the typical soils of the relatively level areas between watercourses. Red and brown Sodosols are the main soils of the levees and occasional slight rises.

Most of the remnant vegetation is woodlands including Low Rises Woodland, Heathy Woodland, Sand Ridge Woodland, Riverine Chenopod Woodland, Plains Woodland, Shallow Sands Woodland and Riparian Woodland. Other vegetation types include Red Gum Wetland, Plains Riparian Shrubby Woodland, Sedge Wetland, Plains Grassland and Freshwater Meadow.

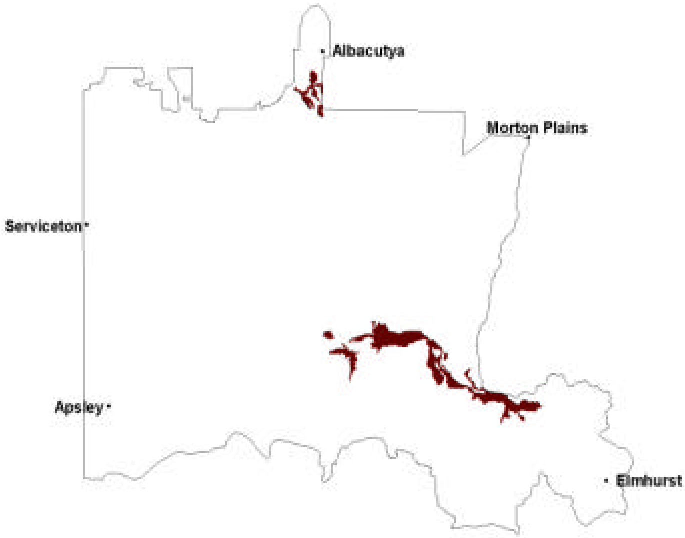
Although little native vegetation remains grey box, buloke, yellow gum and black box all occur singly and occasionally in small stands of these woodlands, grasslands and meadows. Original Plains Grassland vegetation may have included areas of spear grass and wallaby grass.

Factors which could adversely affect agricultural enterprises include landform position, properties of individual soil types and distribution of soil types. With the exception of the current course of the Wimmera River, this landform together with the plain immediately south of the river is the lowest lying area in the Wimmera Trench and as such is subject to occasional extensive flooding which would significantly reduce crop yields. Soil physical properties, such as a hardsetting surface condition on some Sodosols and possibly higher dry bulk densities in some Vertosols, and chemical properties, including high sodicity in deep subsoil, may also indirectly adversely effect crop yield. Diverse physical properties (e.g. the self-mulching condition of Longrenong clay soil type and the massive condition of Murtoa clay soil type) makes cost-effective treatment of the massive surface difficult when these soils situated closely together.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Barrabool sand plains | Sand plain | 45 |
| Horsham lake and lunettes | Lake and lunette | 1 |
| Kalkee plains 2 | Gently undulating plains | 22 |
| Longerenong prior stream plains | Prior stream | 113 |
| Lubeck alluvial plains | Alluvial plain/floodplains | 44 |
| Murtoa flats | Black box flats | 8 |
| Wal Wal prior stream plains | Prior stream floodplain | 219 |

Figure 8  Prior stream plains west of Murtoa near Corkers Creek

## 4.2.2 Plains without leveed channels (Wimmera River – Drung)




The Wimmera River from Greens Creek to Natimuk (defined as the Drung alluvial plains) are characterised by backplains with flats, slopes and stream channels while the modern drainage system has prominent stream banks, channels and drainage lines. In the Horsham area these plains were referred to as representative examples of the floodplain landscape (now referred to as the Drung map unit) and occur mostly south of the Wimmera River. In the east Wimmera Survey (Badawy 1984) soils of the unit comprised the Wal Wal association.

Two topographic features which distinguish this map unit from the Corkers Creek unit (4.2.1) to the north include:

- The absence of a clearly developed channel network. However, a single watercourse in the Drung–Horsham area, parallel to and south of the Wimmera river, does carry water in wet years.
- The presence of two lake and lunette units (4.2.3). The larger and most easterly of the units is 7.5 km south-east of Horsham.

The plains receive flows from all tributaries of the upper Wimmera catchment area including Mount Cole Creek, Wimmera River, Mount William Creek and Concongella Creek. Orientated and running almost east-west for over 80 km, the plains are quite expansive (up to 5 km wide) and reflect once greater fluvial activity in the dissected western uplands. Gradients are very gentle to level with the areas prone to flooding in wet seasons.

The absence of a developed channel network is reflected in the less complex distribution of soil types than that of the neighbouring prior stream plains. Grey Vertosols and red and brown Sodosols are the dominant soils. Important soil types include Horsham clay on the relatively level areas, Murtoa clay which often occurs at slightly lower levels and in local slight depressions, and Drung sandy clay loam which generally occurs on crests and on the upper slopes of slight rises. Each lake and lunette unit (referred to as the Kingcourt map unit) has a unique set of soil types. Bungalally clay (grey Vertosol) occupies the lake beds. Drung sandy clay loam occupies the lunettes. Soil complexes also occur on the lunette of the larger unit.

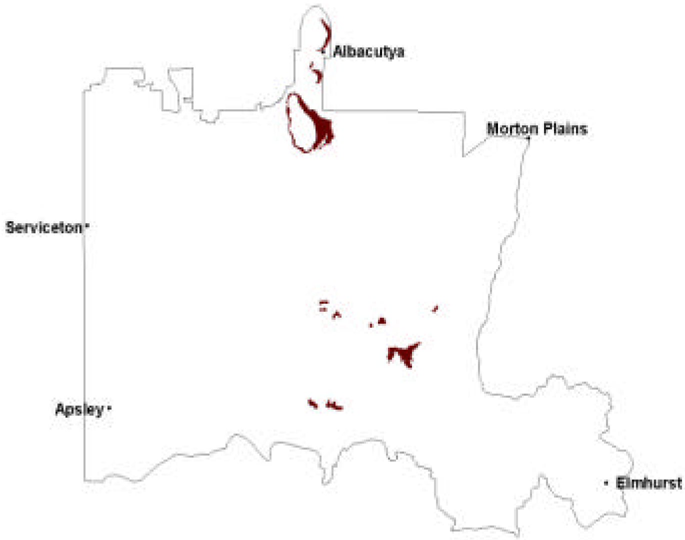
Woodlands are the dominant vegetation type, including communities such as Riverine Chenopod Woodland, Plains Grassy Woodland, Sand Ridge Woodland and Shallow Sands Woodland. Wetlands also occur and are found in creeklines and swampy areas. Land use on these alluvial plains include dryland cropping, pasture production (including lucerne), residential development and recreational activities especially around Horsham. In the Drung soil-landform unit, very little of the original native vegetation remains. Grey box and yellow gum rarely occur. Buloke occurs singly and occasionally in small stands.

Occasional flooding covers a smaller proportion of the area than neigbouring floodplains. Crop losses over the plains from these events would be proportionally less than the prior stream plains. Soil types mimic those of the prior stream plains with the same limitations of their adverse physical and chemical properties also being relevant (e.g. hardsetting surfaces and high sodicity in deeper subsoil). The less complex distribution of diverse soil types may present less difficulty in treating soil structural problems (e.g. hardsetting soil surfaces).

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Barabool sand plains | Sand plain | 32 |
| Drung alluvial plain | Alluvial floodplain | 349 |
| Horsham lake and lunettes | Lake and lunette | 2 |
| Riverside level plains | Level plain | 1 |
| Werrap lake-lunettes | Prior stream plains | 55 |

Figure 9 Wimmera River at Horsham

## 4.2.3 Lakes and basins with lunettes (Lake Hindmarsh, Lake Albacutya)




This land unit occurs predominantly within the Older alluvial plains complex (unit 4.2) as depressions of various sizes and complexity. The larger occurrences are in the north as part of the Lowan Salt Valley in the form of Lakes Hindmarsh and Albacutya with the Wimmera River being the main stream. Smaller examples occur further upstream, east of Horsham as part of the broader alluvial Wimmera River system such as Green, Pine and Taylors lakes. A number of more isolated occurrences are on the broader plains and plain/ridge landscape complexes west and south of the Wimmera River.

These units may be surrounded by older alluvial plains (unit 4.2) as well as modern floodplain units (4.1) on the major drainage systems or isolated units on the plain/ridge complexes (unit 5.5), broad fans and aprons (unit 4.3) or tableland (unit 2.3).

These units are shallow depressions with very gentle slopes with steeper terrain generally on their western shore where they have been eroded out, while there are gentler rises on their eastern shore in the form of lunettes. Some of the larger lakes and depressions have multiple lunettes implying a number of development stages or cycles in which lunettes developed. The lunettes have rounded crests and may be hummocky in profile.

These units have formed in depressions due to a variety of processes such realignment of drainage lines, scouring by drainage lines in variably resistant material, differential deposition and tectonic movement. The larger lakes with multiple lunettes indicate multiple phases of deflation and aggradation, implying they are older than the recent deposition. Deflation of lake bed material by desiccation of salty deposits in arid environments has resulted in lunette development in the direction of the prevailing wind.

Drainage of these features as well as their formation is the result of the amount of water passed through as well as their ability to seal or leak. There is very limited immediate catchment area as well as low precipitation in the current climate.

Organic rich fine sediments tend to dominate the depressions on which cracking clay soils (Vertosols and Sodosols, often self-mulching) have evolved. Fine sands occur around the rim (Sodosols, Tenosols) such as at Lake Hindmarsh. Lunettes often have a deep fine calcareous material regolith with calcareous soils (Calcarosols) which are often highly sodic as well.

Remnant vegetation is comprised mostly of woodland vegetation such as Lignum Swampy Woodland, Plains Woodland, Lunette Woodland, Riverine Chenopod Woodland, Creekline Sedgy Woodland and Low Rises Woodland. At Lake Hindmarsh and Lake Albacutya, Sandstone Ridge Shrubland, Red Swale Mallee, Lowan Sands Mallee, Parilla Mallee, Heathy Mallee and Dunefield Heathland are found. Brackish Lake Mosaic, Red Gum Wetland and Plains Savannah are associated with lakes and back plains. Salt tolerant grasses and forbes occur around lakes and swamps with a succession to trees on the rim material and the lunettes.

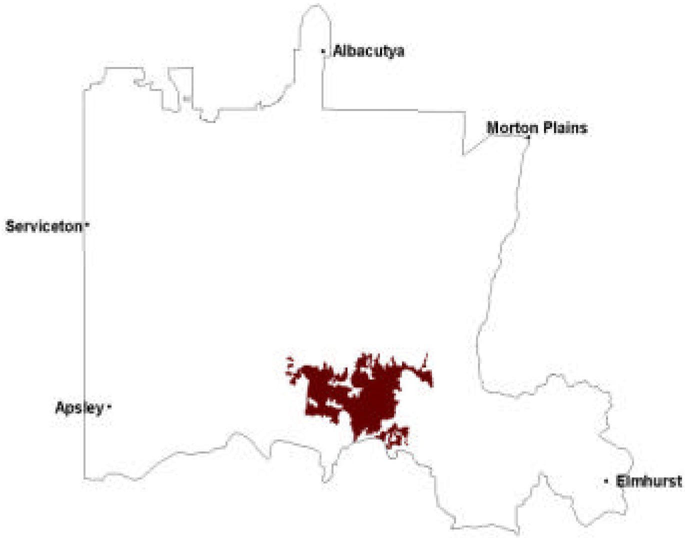
Waterlogging is the major issue, but fluctuating water levels and water quality also have some impact. Scalded (saline) surfaces are susceptible to wind erosion.

Fluctuating water levels and water quality are issues that may wax and wane in importance for land management whether it be for production or natural resource management.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Hindmarsh-Albacutya lunettes | Lunette | 132 |
| Horsham lake and lunettes | Lake and lunette | 11 |
| Horsham lake-lunette cluster | Lake-lunette cluster | 76 |
| Werrap lake-lunettes | Lake-lunette complex | 2 |

Figure 10 Active scald erosion exposing sediments of the Lake Albacutya lunette (note the presence of a second lunette in the foreground)

## 4.3 Pediments, alluvial fans and aprons (Glencoe, Yallambee)




Higher level alluvial fans and aprons occur predominantly on the south side of the Wimmera River, adjoining the consolidated material of the Western Uplands (units 2.1, 2.2, 2.3) from which they were derived. The alluvial fans and aprons extend from south of Horsham to the Douglas Depression in the west and Dadswells Bridge in the east. The alluvial systems extend south into the Glenelg Hopkins CMA region but finish less than 10 km over the catchment divide. Depth of apron material over the underlying older material (consolidated or not) may vary and may be quite shallow with Neogene ferruginised sediments close to the surface in the Brimpaen area and Grampians sandstone north-west of the western Black Range. Apron and alluvial plain sediments belong to the Shepperton Formation where once extensive fluvial systems extended across much of the Murray Basin. These unconsolidated sediments conformably overlie the Neogene Parilla sand. The lithology of this formation is largely a mix of gravels, sands and silts that through groundwater fluctuations combined with pedogenesis have altered the nature of these sediments.

The major streams which flow north across the plains between the Grampian Ranges and Horsham are Norton Creek, the Mackenzie River and its tributary Bungalally Creek, and Burnt Creek. All are tributaries of the Wimmera River. Burnt Creek flows across the Drung floodplain before entering the Wimmera River near Horsham. All these streams are relatively inactive. This feature together with the even shallow slope, a drop of over 30 m from south to north over a distance of at least 20 km, suggests a stagnant alluvial plain landform pattern superimposed on an apron of material derived in part at least from the Grampian Ranges. Several different map units surround the near isolated plain. These include the Grampian Ranges to the south and south-east, the St Helens gentle plains and Drung alluvial plains soil-landform units to the north and the relatively elevated Darragan rolling rises unit to the north-west. An area of isolated and clustered lake and lunettes, now mapped as the Kingcourt and Pine Lake soil-landform units respectively, occupy areas to the south-west.

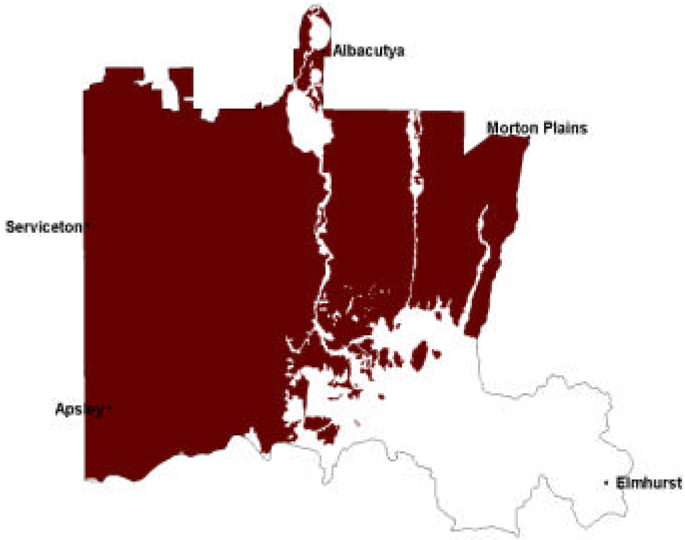
The variety of soils which occur on the plain include grey Vertosols, brown Sodosols and yellow and brown Kandosols. Sandsheets (Barrabool map unit) are also present. Within the plain there may be a possible subdivision based on the proportions of Vertosols relative to Sodosols and Kandosols (i.e. the Yallambee with the greater area of Vertosols than the Glencoe map units). Some soil properties may well be limiting factors to primary production. For cereal production these include the coarse blocky structure and the very strong (i.e. very hard) consistence of both surface soils and subsoils of some Vertosols and the strong consistence of the surface soils of some Kandosols.

Remnant vegetation communities on the flat plains and sandy clay plains are dominated by woodlands including Plains Woodland, Shallow Sands Woodland, Damp Sands Herb-rich Woodland, Heathy Woodland, Creekline Sedgy Woodland, Dry Creekline Woodland, Sand Ridge Woodland, Shrubby Woodland, Riparian Woodland, Red Gum Wetland and Plains Grassy Woodland.

| Soil-landform unit | Unit description | Area (km$^2$) |
|---|---|---|
| Barabool sand plains | Sand plain | 46 |
| Horsham lake and lunettes | Lake and lunette | 16 |
| Horsham lake-lunette cluster | Lake-lunette cluster | 7 |
| Horsham south flat plains | Stagnant alluvial floodplain | 375 |
| Horsham south sand-clay plain | Sand and clay plain | 319 |
| Quantong dunes and swales | Dune and swale | 12 |

Figure 11 Looking north-east over the alluvial aprons and plains with Mount Zero in the distance

# 5 North West Dunefields and Plains




The North Western Dunefields and Plains are clearly defined from the Western Uplands and from the relatively flat Northern Riverine Plains in the north and east. Elevations decline from about 200 m in the south to 40 m in the north.

The climate is mostly semi-arid, but it ranges from almost arid in the north to sub-humid in the south. The central and northern parts are known as the 'Mallee' after the dominant native multi-stemmed eucalypts. In the Wimmera the original vegetation was mostly grassy woodlands of eucalypts and buloke (*Allocasuarina luehmannii*) before being superseded by dryland cereal cropping. Drainage systems have not been developed in the drier areas where scant rainfall is readily absorbed by porous soils. Most surficial materials are aeolian, but there are some alluvial valley deposits in the south along ephemeral stream courses that mostly terminate before reaching the central areas. Some lacustrine and evaporite deposits are found in the centre and north.

Smaller and fairly regularly spaced ridges, typically scores of kilometres long and trending north-north-west, originated as beach ridges when the Pliocene sea retreated westwards. The stranded ridges and intervening swales where then laterised, producing a regolith some metres deep. Radiometric imagery shows the stranded ridges to be present everywhere but in the major depressions where they have been eroded or buried.

This landscape was modified by movements in the Palaeozoic bedrock (producing a fall to the north–west), several broad depressions and relatively large ridges which trend mainly NNW-SSE. These ridges have greatly affected sedimentation in the north, particularly in the Tyrrell Depression and on either side of the Sunset Strip, a horst-like structure to the east of the Danyo Fault which runs from near Murrayville north-eastwards almost to Mildura. To the west of Murrayville there is another ridge, the Pinnaroo Block, which extends from the Wimmera into South Australia.

The Pinnaroo Block dammed back the River Murray some 2.5 mya forming a huge lake system covering parts of what are now South Australia, New South Wales and Victoria. Large lakes occupied the broad depressions, largely removing the stranded ridges, presumably by wave action. The lacustrine deposits, mainly grey clay (Blanchetown Clay, Firman 1965) may be more than 30 m thick in the major depressions, but are now mostly buried. Bores have revealed their presence in most of the Victorian Mallee except beneath the Big, Little and Sunset deserts (three east-west belts of land which continue on into South Australia). Blanchetown Clay has also been noted to occur discontinuously beneath about half of the Wimmera, mostly towards the west.

Alluvial and aeolian deposition also occurred during the Pleistocene. The alluvial Shepparton Formation (Lawrence 1966) accumulated between the stranded ridges. Very hard blocks and sheets of limestone a metre or more thick sometimes outcrop, particularly in the western parts of the Ouyen-Murrayville and Millewa settlements. Such deposits, known as 'Bakara Calcrete' are widespread in South Australia. The material is thought to be derived from loess stripped from the coast. Leaching concentrated the carbonates in the subsoil which hardened when exposed by erosion. Surfaces are now stable, being protected by a litter of limestone.

During the mid to late Pleistocene, a series of arid phases led to the development of dunefields. Lacustrine, aeolian and alluvial deposits gave rise to the Woorinen Formation (Lawrence 1966), calcareous material of variable clay content on which linear dunefields are prominent. Areas where laterised Parilla Sand had remained at the surface were wind sorted producing Lowan Sand (Lawrence 1966) - the siliceous sand of the Big, Little and Sunset deserts which contain linear and parabolic dunes.

## 5.1 Calcareous dunefields (Woorinen Formation)


Much of the region is blanketed by the aeolian Woorinen Formation, a multilayered deposit of variably calcareous sands, loams and clays. Generally two or more metres thick, soils are characteristically yellowish red to reddish yellow in colour. The dunes are set on plains and ridges of variable prominence. East-west dunes predominate, but in the south-eastern Mallee there are subdued, sub-rounded, hummocky forms. The modern soil is underlain by three or more palaeosols which were partly eroded before burial (Churchward 1961, 1963a, 1963b). The layers tend to parallel the land surface. Within each layer the contents of clay, carbonates and soluble salts increase from dune crest to swale. Instability occurred during arid glacial periods extending back to about the middle Pleistocene.

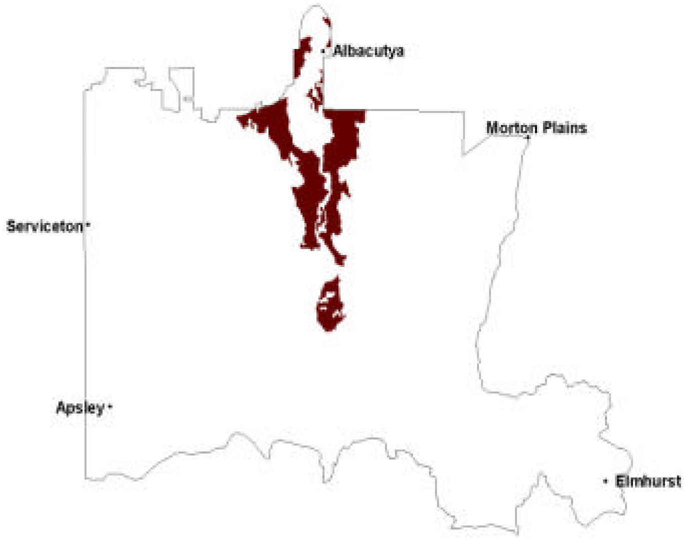
Carbonates occur as soft material, nodules and angular stones. However, very hard blocks and sheets of calcrete a metre or so thick outcrop intermittently in the western parts of the Ouyen-Murrayville and Millewa settlements. Such calcrete is particularly widespread in South Australia as 'Bakara Calcrete', and is thought to have developed in earlier loess deposits derived from the coast. Leaching of the loess concentrated lime in the subsoils that hardened when exposed by erosion. Materials that had been removed became part of the Woorinen Formation.

On the linear dunes, loose sands overlie compact sandy loam to sandy clay loam. Swales generally have medium-textured soils with sandy loam to sandy clay loam surfaces, merging gradually with depth to sandy clay or clay subsoils with abundant carbonates which may exceed one-third of the subsoil (Rowan & Downes 1963). Contents of soluble salts are typically high in the subsoils of lower positions. Surface reaction tends to be neutral in the loose dune sands, but alkaline elsewhere. Surfaces are naturally friable and porous, but may be hardened by erosion and over-cultivation.

The light- to medium-textured soils, both Calcarosols, occupy most of the dunefields. However, gilgaied clay soils known as Vertosols predominate on plains and gentle ridge slopes in the southern Mallee, continuing on into the Wimmera. Carbonate contents are lower than those in the Calcarosols, but soluble salt contents are higher. The parent materials are thought to be 'parna' (Butler 1956; Butler & Hutton 1956), a fine-textured aeolian material deposited from suspension rather than by saltation.

The formation of linear dunes from loamy and clayey materials is thought to have been promoted by surface salinity in the lower situations during arid periods that initially had high watertables. Surfaces became saline through evaporation, producing bare, loose surfaces susceptible to deflation. Sand and clay aggregates saltated to form dunes, apparently with little downward movement.

### 5.1.3 Linear dunes sub-dominant (Lowan salt valley,Antwerp)




Around Peppers Plains (west of Jeparit) and also buffering the western side of the Wimmera River, a regular series of north-north-west to south-south-east trending ridges upon which east-west dunes are superimposed represents margin (transition) between what was known as the Northern Wimmera and Southern Mallee.

These ridges are separated by distances of 800 m to in excess of 1500 m (Rowan & Downes 1963) and represent stranded beach ridges from the marine regression during the later Pliocene. The later forming dunes are weakly developed and occupy little of the landscape with relief across these landforms typically less than 10 m. Woven between ridges are gentle to level slopes that support gilgaied cracking clays.

Gilgaied clay soils (Vertosols) predominate on the inter-ridge plains and on lower ridge slopes. Medium-textured Calcarosols tend to occupy middle and upper ridge slopes where the native vegetation is mainly mallee. The heavier soils of the lower positions have stands of big mallee. Reddish yellow sands predominate on these superimposed east-west dunes, with compact subsoils.

Native vegetation dominated by mallee except on dune crests where mallee savannah occurs (Rowan & Downes 1963). Vegetation includes woodlands, mallee and shrubland. Some of the more prevalent vegetation communities include Low Rises Woodland, Lowan Sand Mallee, Sandstone Ridge Shrubland, Ridged Plains Mallee, Parilla Mallee, Red Swale Mallee, Woorinen Mallee, Ridged Plains Mallee, Plains Woodland, Lignum Swampy Woodland, Shallow Sands Woodland and Plains Savannah. Overall, remnant vegetation is small mallee with porcupine grass understorey. Pine and belah woodlands occur widely on high ridges where grasslands are also common. In these areas the soils are mostly red brown medium-textured calcarosols.

The land is mostly devoted to agriculture. The overall erosion hazards of the landscapes are reduced by the lower proportion of dunes and by the widespread clay soils. However, the salinity hazard is severe in the southern Mallee where the rainfall is higher. Water seeps from the dunes perched on clay layers of low permeability, raising the watertable beneath the swales where soluble salt contents are high (Rowan 1971). Evaporation produces saline surfaces. Reclamation involves reducing seepage with deep-rooted species on the dunes. Yields are also reduced by the inherent salinity of the clay soils, particularly on gilgai puffs. In addition, sodicity at the surface of puffs impairs tilth.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Dimboola rises | Gently undulating rises | 166 |
| Hopetoun rises and swales | Undulating rises | 329 |
| Horsham lake and lunettes | Lake and lunette | 3 |
| Horsham lake-lunette cluster | Lake-lunette cluster | 2 |
| Kiata rises | Gently undulating rises | 64 |
| Lowan Salt Valley | Valley plain | 349 |
| Murra Warra West gentle rises | Gentle rises | 9 |
| Nhill lake and lunettes | Lake-lunette | 13 |
| Perenna undulating sand plains and rises | Gently undulating sand plains | 85 |
| Quantong dunes and swales | Dune and swale | 4 |
| Vectis undulating rises and low hills | Undulating rises and low hills | 119 |
| Werrap lake-lunettes | Lake-lunette complex | 4 |

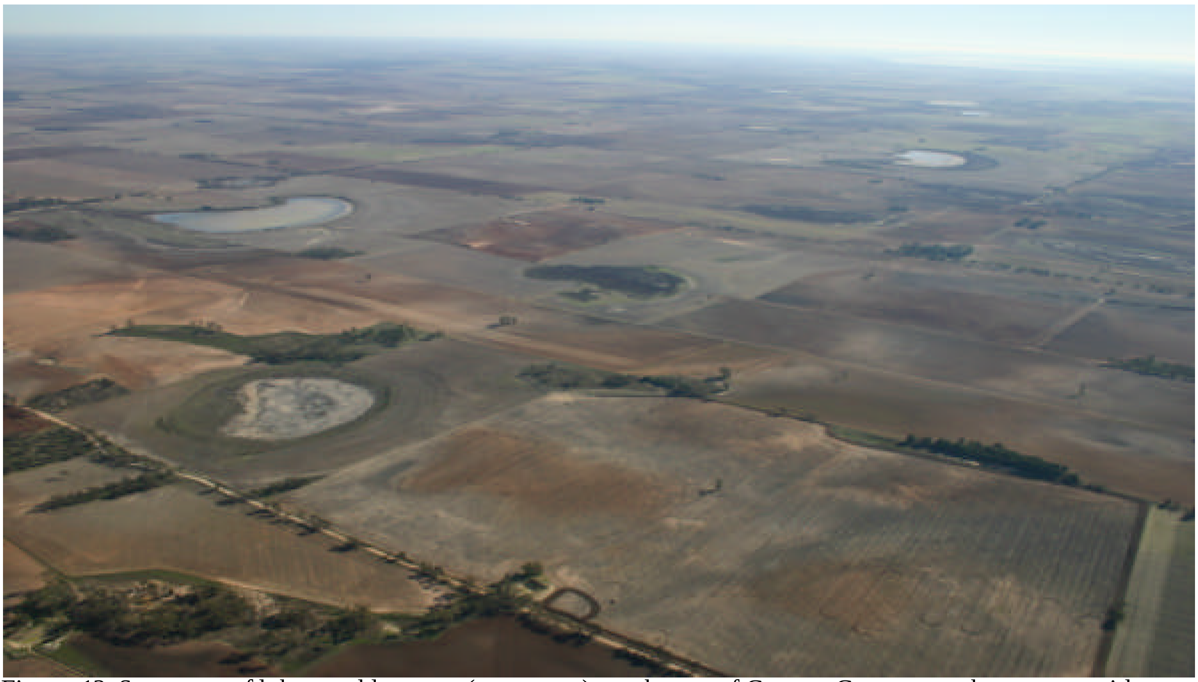
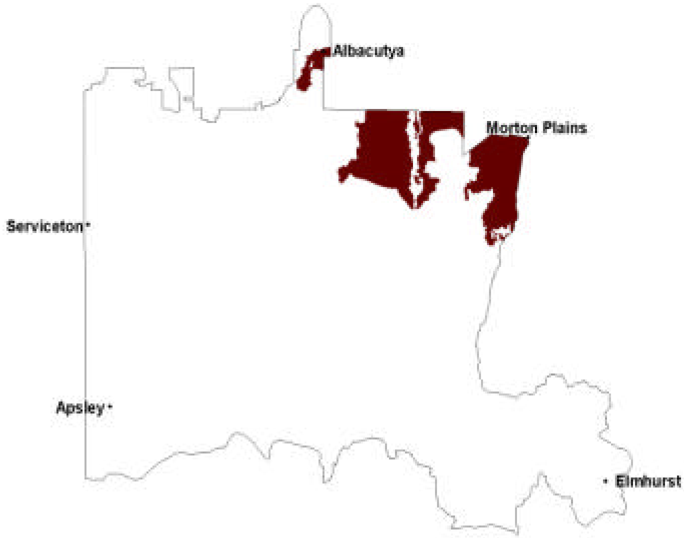


Figure 12 Sequence of lakes and lunettes (gypseous) north-east of Gerang Gerung on the western side of the Wimmera River

## 5.1.5 Hummocky dunes sub-dominant (Hopetoun, Peppers Plains)




Across the north-west corner of the WCMA region (running from Yellangip to Wilkur South) are plains on which there are scattered low hummocks. Known from previous reports as the Culgoa landsystem (Rowan & Downes 1963), the scattered low hummocky dunes tend to occur in cluster ranging up to some 3 km across. Unlike unit 5.1.3, subdued ridges with superimposed recent dunes are absent from surface expression within this landscape. As a result, relative relief across these landforms is much lower than neighbouring landforms of landscapes to the north.

The eastern boundary is irregular but clearly defined from riverine plains of the Richardson and Avoca rivers. In the south-west this unit abuts the Lowan Salt Valley which is readily defined through its entrenched nature as evident in Digital Elevation Models (DEM). To the south the boundary is regarded as a transition and notes the heralded change from the Wimmera to the Mallee. Further refinement using suitable imagery and detailed field work are needed to locate the boundary accurately.

The plains on which the dunes occur are generally subdued. Slopes are gently to very gently inclined with gentle rises, undulating plains and level plains being the dominant landscape features. Drainage systems are few and far between with lake and lunette clusters found north-west of Donald. Hummocks are more evident where superimposed on rises further north where underlying stranded beach ridges give a more pronounced affect to the landscape. The Yarriambiack and Dunnmunckle creeks run northwards through these calcareous dunefields where they have dissected the clay plains leaving the well defined stream channels that are less apparent further north. Woorineen Formation aeolain sands and silts are the primary source for these hummocks.

Gilgaied clays are by far the most widespread soils, occupying the plains and the gentler dune slopes. These cracking clays are often dark and self-mulching with vertic medium clay subsoils that may have calcareous segregations present. Sodic, red, grey and yellow texture contrast soils (Sodosols) are more prominent on dune slopes and hummocks. Surfaces of these soils are sandy loams with strong change to medium clay subsoils that are extremely sodic in nature. Colour for these subsoils is often a good hydromorphic indicator with red variants usually found higher in the landscape.

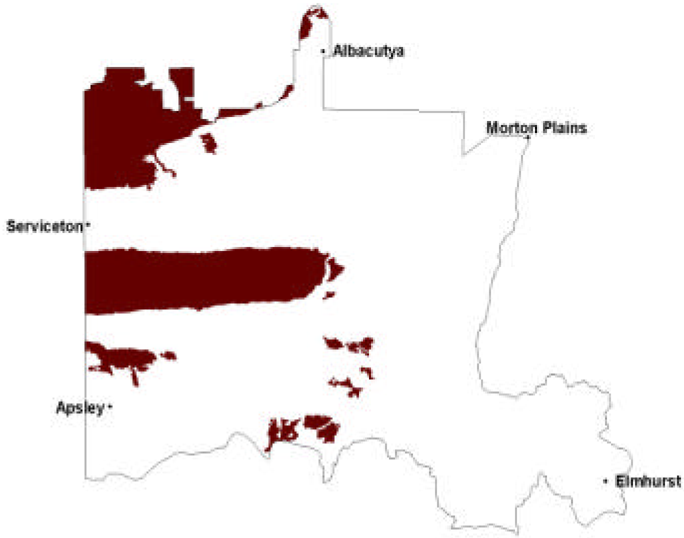
Remnant vegetation consists of a variety of mallee, woodland and shrubland vegetation. Vegetation communities recorded include Parilla Mallee, Plains Savannah, Ridged Plains Mallee, Red Swale Mallee, Sandstone Ridge Shrubland, Riverine Chenopod Woodland, Plains Woodland, Low Rises Woodland, and Lignum Swampy Woodland that is associated with creeklines and swampy areas. Plains Grassland, Plains Woodland and Plains Savannah are more common in the north-east. Mallee species are scattered and widespread with remnant vegetation open stands of big mallee found on plains with heavy soils, and medium mallee on the dunes. Scattered remnants of pine and buloke woodland are also prevalent in this area of the WCMA region.

Agricultural production is limited on the clay soils because of low storage of available water under the semi-arid climate, and this effect increases with increasing aridity towards the north. The wind erosion hazard is high only on upper western dune slopes. Seepage salinity has not been noted.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Beulah plains | Gently undulating plains | 54 |
| Brim undulating rises | Gently undulating rise | 123 |
| Charlton gentle rises | Moderately undulating plains | 218 |
| Donald lake-lunettes | Lake-lunette system cluster | 28 |
| Hopetoun rises and swales | Undulating rises | 660 |
| Jerro eroded ridges and slopes | Eroded ridge and slopes | 56 |
| Kalkee plains | Gently undulating plains | 86 |
| Kalkee plains 2 | Gently undulating plains | 94 |
| Morton drainage plains | Drainage lines | 18 |
| Murra Warra East gentle rises | Moderately undulating plains | 83 |
| Rainbow hummocky dunes and plains | Hummocky dunes | 86 |

Figure 13 Long gentle slopes with subdued rises near Warracknabeal

## 5.2 Siliceous dunefields (Little Desert, Big Desert)




Three clearly defined tracts of Lowan Sand - the Big Desert, the Little Desert and the Sunset Desert - extend eastwards from the South Australian border. The smallest (the Little Desert) is about 25 km wide, and extends as far as the Wimmera River. The largest (the Big Desert) is 96 km wide along the South Australian border, narrowing towards the east. To the east of Outlet Creek and the Wirrengren Plain which marks the termination of the Wimmera River System, the Big Desert splits into two arms enclosing calcareous dunefields. The northern arm reaches almost to Lake Tyrrell. The Sunset Desert, 35 km wide at the border, also narrows towards the east where it almost reaches the Hattah Lakes.

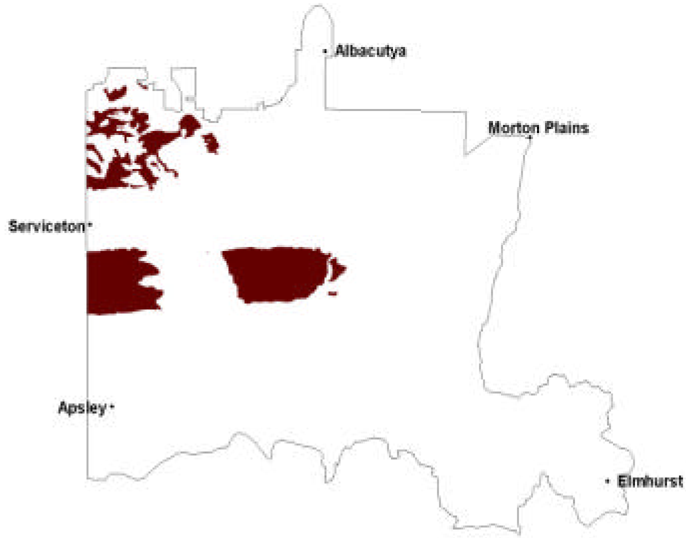
The Big Desert, Little Desert and Sunset Desert sandy tracts that link up in South Australia, have surfaces of Lowan Sand derived largely by deflation of the laterised Parilla Sand ridges. Within all three areas there is a complex alternation of sub-parabolic and linear dunefields, mostly aligned in east-west belts with clear boundaries between them. Linear dunefields occupy most of the Little Desert. Parabolic dunes predominate in the Big Desert except to the east of the Wimmera River system where they are absent. Linear dunefields are a little more common in the Sunset Desert.

The parabolic dunes appear to have developed by partial erosion of linear dunefields. The arms of the parabolic dunes are aligned south-west to north-east, the dominant direction of present day strong winds. Hill and Bowler (1995) have noted dunes in southern Victoria with similar orientation which they relate to the modern wind regime. That the parabolic dunes are younger is supported by their weaker soil development. Their soils lack development other than accumulation of surface humus, unlike the linear dunefields where B horizons are quite well developed.

Stranded ridges are prominent in the Little Desert, mostly subdued in the Big Desert (except in the south-west and to the east of the Wirrengren Plain) and not apparent in the Sunset Desert except on the Sunset Strip. The Shepparton Formation, mostly clayey, was deposited between low-lying ridges, but is almost entirely covered by Lowan Sand. These sands overlie Blanchetown Clay in depressions. The Sunset Desert crosses the Noora Depression in the west and the Raak Depression in the east. The Big and Little deserts cross the depression occupied by the Wimmera River system. The deserts also overlie the Woorinen Formation near their margins.

These areas largely remain under indigenous vegetation, being of low soil fertility and very prone to wind erosion when disturbed. The predominant mallee thickets have a diverse understorey, forming excellent conservation reserves such as the Little Desert National Park and the Murray Sunset National Park.

## 5.2.1 Parabolic dunes




Within the Little Desert and Big Desert the landscape has been fashioned into a complex array of undulating sand plains, east-west aligned dunes and jumbled dunes. The largest individual areas of parabolic dunefields occur in the Big Desert in three east-west swathes to the west of the linear depression containing the Wimmera River system. The swathes are some 10-20 km wide and up to 90 km long. These dunefields include a broad ridge running south-east from the Pinnaroo Block as well as stranded ridges and associated swales. The northernmost swale crosses the fringe of the regional depression to the east of the Sunset Strip.

The parabolic dunes (jumbled dunes) are areas of juvenile dunes (Hills & Bowler 1995) with sediments defined as Lowan Sand (Lawrence 1966) and were derived from deflation of underlying Pliocene Parilla Sand (remnant stranded beach ridges). These parabolic dunes are often large, with sharp crests (not stabilised by vegetation), often enclose wide heathy sand plains and are interspersed with smaller, smooth-crested dunes of variable orientation with no defined drainage. The arms of the parabolic dunes trend south-west to north-east as do the present dominant strong winds, evidence that the landforms are young (Joyce et al. 2003).

Orientation of the dunes is variable, but mostly south-west to north-east. Large sub-parabolic forms with sharp crests are common, with arms opening towards the south-west and with slip faces to the south and east. The dunes tend to be irregular along their crests rather than straight or smoothly curved, and there may be small, barchanoid segments. The parabolic dunes often enclose large plains 1 km or more across. These plains may contain small sub-rounded to linear dunes of variable orientation. The small dunes are mostly smooth-crested.

The major soils are Rudosols. Humus has accumulated at the surface except on unstable dune crests. Below the humus there are deep, loose, yellow sands over the whole landscape. In profiles examined to the south of Murrayville, coarse sand predominated and carbonates were confined to occasional flecks. The reaction was neutral in the top metre or so, but alkaline below this. Values for all plant nutrients examined were low (exchangeable metal cations, nitrogen and potassium). Lowan Sand is also known to be deficient in trace elements such as copper and zinc.

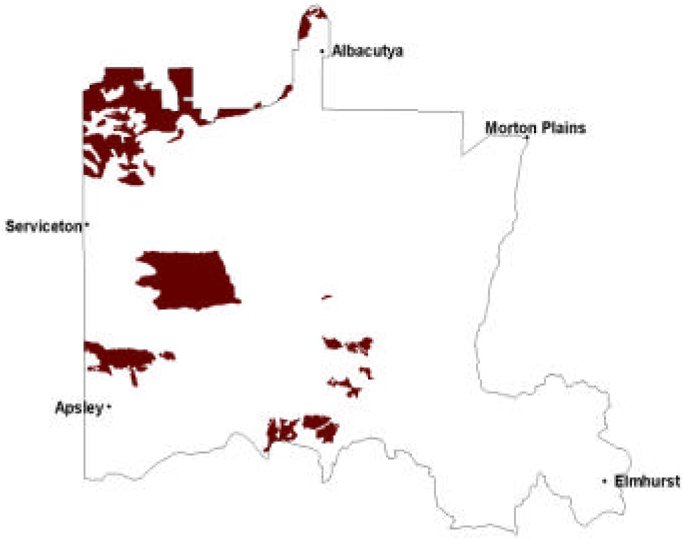
Vegetation across the three deserts varies with the large shift in climate. Average annual rainfall declines from 500 mm in the Little Desert to less than 300 mm in the Sunset Desert, and temperatures increase in the same direction. In the Big and Little deserts heathlands predominate with vegetation communities including a range of woodland, heathland and mallee vegetation. Prominent communities include Shallow Sands Woodland, Plains Woodland, Sandstone Ridge Shrubland, Heathy Mallee and Lowan Sands Mallee. Other vegetation communities include Dunefield Heathland, Low Rises Woodland, Plains Woodland, Parilla Mallee and Red Swale Mallee. Red Gum Wetland and Seasonally Inundated Shrubby Woodland have also been found in wetter areas of the landscape.

An abundance of species includes genera such as *Banksia*, *Xanthorrhoea* and *Epacris*. These species sometimes form an understorey to mallee eucalypts, particularly along sheltered slip faces, the stands being known as 'mallee-heath'. In the Sunset Desert, aridity is too great for heath which is replaced by mallee scrub with a prominent understorey of tea-tree.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Big Desert jumbled dunes | Sandplain with jumbled dunes | 478 |
| Diapur ridge | Beach ridge and dunes | 93 |
| Goroke plains and rises | Plains with prominent ridges | 118 |
| Kiata rises | Gently undulating rises | 19 |
| Little Desert linear dunes | Linear dunes | 22 |
| Little Desert parabolic dunes | Parabolic dunes | 1064 |
| Nhill lake and lunettes | Lake-lunette | 2 |
| Wail parabolic dunes | Parabolic dunes | 33 |
| Woorak clay plains | Grey clay plains | 18 |

Figure 14 Jumbled dunes of the Big Desert

## 5.2.2 Linear dunes




Linear dunes within the WCMA region can be found in the Little Desert and Big Desert along with patches south-west of Horsham (Vectis South-Lower Norton area). Siliceous sediments of these linear dunes, defined as Lowan Sand (Lawrence 1966), were derived from deflation of underlying Pliocene Parilla Sand (remnant stranded beach ridges). Developed from aeolian processes, these dunes provide a landscape that represents large areas of remnant dense scrub that are clearly visible from satellite imagery. These siliceous dunes are closely spaced (dense dunes) and low with narrow sandy swales and relief is typically less than 10 m. Southern slopes and flanks are consistently steeper (Hills 1975) with wavy smooth crests that are more stable than parabolic dune equivalents that lack significant vegetation cover. Minor landforms include sinkholes and swamps in the south-west in these narrow sandy swales (Ollier & Joyce 1986) with drainage very poorly defined to non-existent.

The linear dunefields overlie similar landforms to those beneath unit 5.2.1. The dunes tend to be low, smooth-crested and wavy, with an overall east-west alignment. The swales are mostly narrow and sandy. In low sites such as the plains between stranded ridges the Lowan Sand may be shallow or absent, exposing fluvial, lacustrine or aeolian sediments. Around the desert margins, reddish materials are common on broad flats, probably representing the Woorinen Formation.

Tenosols developed on Lowan Sand have significant profile development both on dunes and swales. Below the surface layer with humus accumulation the A horizon is an off-white sand, mostly more than 1 m thick. There is a sharp change to yellowish-red, somewhat compact clayey sand B horizons with yellow and grey mottles. Reaction in the profiles examined was neutral in the upper sands and alkaline in the B horizons. Soluble salt contents were low throughout with dunes and swales relatively infertile due to high sand concentrations.

Diverse soils have been noted in the scattered low sites where the Lowan Sand is shallow or absent, including Sodosols, grey weakly-structured Vertosols and Calcarosols around the desert margins.

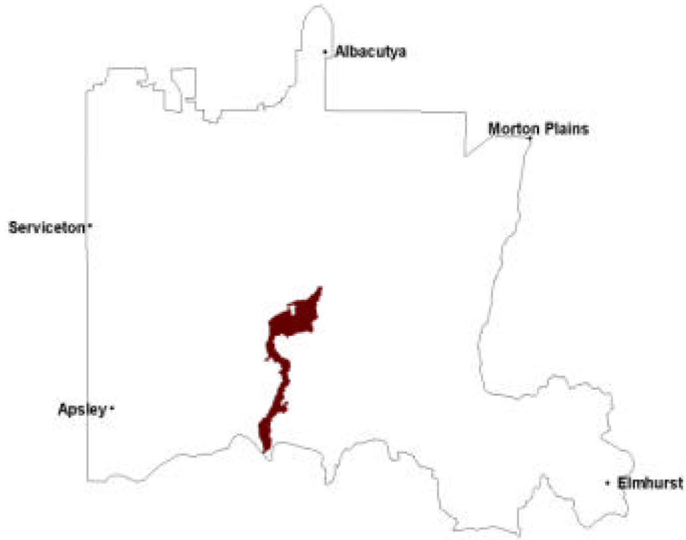
Siliceous linear dunes or sandstone ridges and rises are associated with mallee vegetation communities such as Lowan Sands Mallee, Heathy Mallee (honeysuckle, scrub pine, tea tree, blackboy, sheoak and heath), Ridged Plains Mallee and Loamy Sands Mallee. Prominent shrub understorey includes genera such as *Leptospermum, Callitris, Baeckea* and *Melaleuca.*

Other significant vegetation communities include Shallow Sands Woodland, Low Rises Woodland, Heathy Woodland, Dunefield Heathland, Sandstone Ridge Shrubland, Red Swale Mallee, Ridged Plains Woodland and Parilla Mallee. On flats lacking Lowan Sand the mallee stands are taller and have a sparse understorey. In drier areas the common pattern is small mallee and porcupine grass on the dunes, mallee with tea-tree on sandy swales, and mallee in the lowest sites with heavier soils.

| Soil-landform unit | Unit description | Area (km²) |
|---|---|---|
| Big Desert dense dunes | Dense linear dunes | 995 |
| Darragan rolling rises | Rolling rises | 3 |
| Diapur ridge | Beach ridge and dunes | 194 |
| Horsham lake and lunettes | Lake and lunette | 1 |
| Horsham lake-lunette cluster | Lake-lunette cluster | 14 |
| Horsham south flat plains | Stagnant alluvial floodplain | 1 |
| Little Desert linear dunes | Sand plains and linear dunes | 429 |
| Nhill lake and lunettes | Lake | 5 |
| Quantong dunes and swales | Dune and swale | 236 |
| Tallageria swampy sand plains | Swampy sandplain | 204 |
| Woorak clay plains | Clay plains | 1 |

Figure 15 Linear dunes of the Big Desert

## 5.3 Depressions



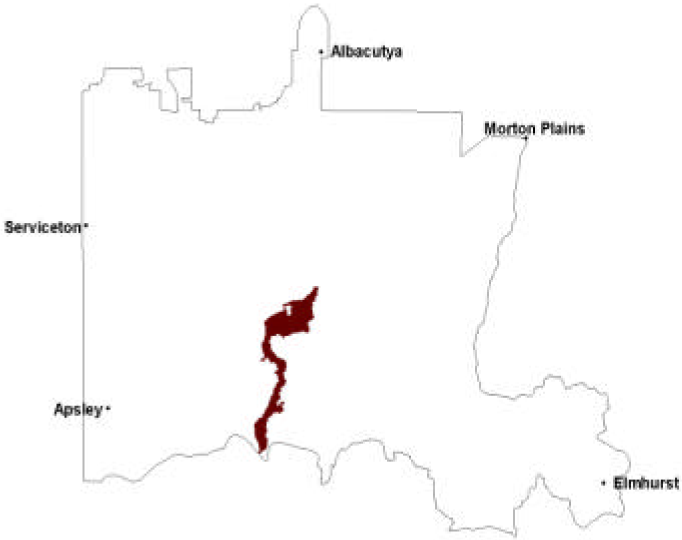

Distinctive landforms are found in the lower parts of the Tyrrell, Raak and Noora depressions, the margins of which approximate to the 60 m contour.

Relatively large lakes which are now saline occur in the Tyrell Depression, the largest being Lake Tyrrell which is the termination of Tyrrell Creek, an effluent from the Avoca River. Lunettes separate Lakes Tyrrell, Wahpool and Timboran, evidence that the whole area was once inundated. Lalbert Creek, another ephemeral effluent from the Avoca River, terminates at Lake Timboran.

The very large Raak Depression extends from the Mildura area to the Raak Plain. From here there is a south-westerly extension reaching almost to Murrayville, on the eastern side of the Sunset Strip. There is another broad extension to the area around Ouyen. A linear arm extends southwards from the Wirrengren Plain along what is now the course of the Wimmera River. The Douglas Depression forms part of this linear feature.

Most of the Noora Depression lies in South Australia, and its eastern limit is the Sunset Strip. This limit is indented, apparently marking a shoreline of the former Lake Bungunnia.

## 5.3.3 Salt lake depression (Douglas Depression)




This third tier sub-division is made up of one large continuous unit located in Western Victoria; one of the most southerly occurrences of the Dunefields and Plains geomorphological Division (Tier 1; 5).

The northern boundary is with the Little Desert (unit 5.2) and the Wimmera River (unit 4.1) whose broad valley forms a continuing depression link to depression units further north. The Douglas Depression is at its widest here, about 8-9 km across, decreasing in width further south. To the west of the depression and to some extent to the east lies a complex of ridges and depressions, the ridges often subdued (unit 5.5.2). The degree and clarity of incision of the Douglas Depression in the landscape varies, probably most defined by its deflection around Mount Arapiles (unit 5.6), an inlier of the Grampians sandstone complex. The depression is dominated by a series (chain) of lakes, of which most are saline. The depression width varies from 2-3 km near Natimuk and 4-5 km to the south of Douglas where larger lakes (e.g. White Lake) occur. The depression surfically peeters out (after about 85 km from the Wimmera River) to the south of White Lake on encountering the Dundas Tableland (unit 2.3), which rises gently to the south before being dissected by the Glenelg River.

Extending north-east of Harrow to the Little Desert, the shallow sinuous north-sloping valley comprises a suite of landforms including gentle valley inclines, almost level plains, backplains and lunettes associated with salt and freshwater lakes. This depositional system is characterised by gentle slopes that reflect reliefs of 10 m. Lakes here are significantly larger than lakes further north within the Lowan Salt Valley. Drainage is poorly defined with no through system recognised.

The Douglas Depression is an area of saline discharge, as evidenced by the lake systems (often with lunette formations) and varying periods of water present, and is likely to be structually controlled. The depth and age of regolithic material in the depression is not well known. Regolith is typically alluvial sourced including significant deposits of clay and gypsum that are strongly associated with salinas and lunettes during arid dune-building phases (Bowler 1976; Hill & Bowler 1995). It should be noted that similar formations of stranded beach ridges occur on both sides of the Douglas Depression (the ridges were formed approximately 4 Ma). There is an incursion of Lowan Sand across the depression to the north of Douglas, somewhat masking the depression and the older ridge material. There is speculation, given the sharp flow direction change of the Wimmera River that the depression is a paleochannel of a south to north flowing stream or indeed a north-south stream before the uplift (doming) of the Dundas Tableland (unit 2.3); some form of river capture has taken place. Another theory is that this was an outlet for a former lake (Lake Bungunnia) as the inland sea of the Murray Basin retreated.

The depression is an extension of what is known as the Lowan Salt Valley. The climate becomes milder and moister south of the Little Desert thus the calcareous soils and mallee vegetation start to disappear southwards; the Lowan Salt Valley is the most southerly incursion of mallee type environment into the riverine environment further south.

The Douglas Depression has a range of soils from calcareous earths (Calcarosols) in the north to sodic and saline texture contrast and cracking clay soils to the south and amongst the lakes and swamps. These texture contrast soils and heavy variants are prone to seasonal waterlogging with very poor site drainage. While sandy soils (Kandosols) can occur as aeolian sand spill overs from the western plains, most soils are extremely sodic at depth and often saline when in association with salinas.

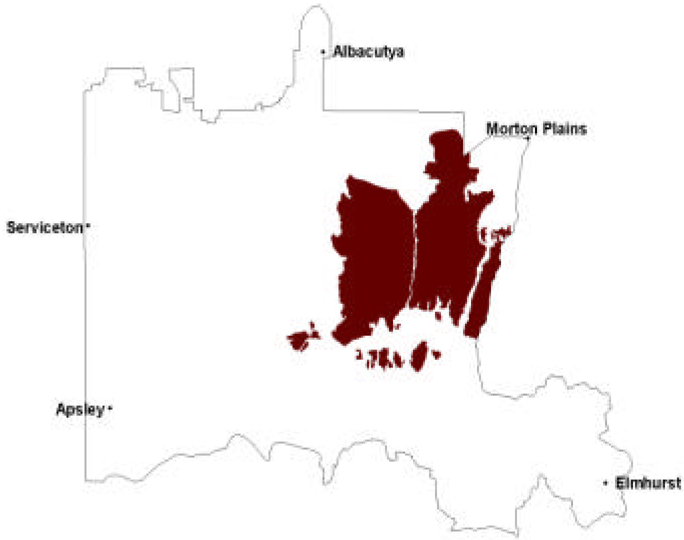
Vegetation communities include a number of woodland and wetland associations including Heathy Woodland, Plains Woodland, Low Rises Woodland, Riverine Chenopod Woodland, Seasonally

Inundated Shrubby Woodland, Lunette Woodland, Plains Woodland and Salt Paperbark Woodland. Other vegetation communities include Aquatic Herbland, Plains Savannah, Ridged Plains Mallee and Dunefield Heathland. The depressions are also associated with a number of vegetation communities that grow in saline conditions including Lignum Swampy Woodland, Brackish Sedgeland, Red Gum Wetland, Plains Savannah, Brackish Wetland, Inland Saltmarsh, Samphire Shrubland and Saline Lake Mosaic, as well as permanent and semi-permanent saline wetlands.

| Soil-landform unit | Unit description | Area ($km^2$) |
| --- | --- | --- |
| Douglas lake and lunettes | Lake and lunette | 58 |
| Natimuk-Douglas valley | Shallow valley | 293 |

Figure 16 Lakes and lunettes (White Lake and Centre Lake) at Douglas

## 5.4 Clay plains with subdued ridges (Minyip)




Boundaries between the clay plains and surrounding geomorphic divisions (4.1, 4.2, 5.1) vary from sharp (within 1 km) to broad marginal areas covering up to 20 km. The characteristic and distinguishing feature of this terrain is the soils of the unit; grey and brown cracking clays (often friable or self-mulching) or Vertosols.

In the south and south-east there are fairly sharp transitions from grey Vertosols to a variety of texture contrast and shallow stony soils on the Western Victorian Uplands. Also, west of Horsham, grey clay dominant soils end abruptly just east of the Wimmera River, although isolated areas of these friable clay Vertosols do occur west of the river. Areas of the stagnant alluvial plains near the south-west corner of the unit are at the level of subdued ridges and merge imperceptibly with the extensive plains of the Goroke unit. Along the north-west boundary of the unit (from Dimboola north-east to Birchip), the clays merge with areas of dominantly Calcarosols which are soils of the Woorinen Formation. In the north-east (the Charlton area) red Sodosols are the dominant soils. This area represents a broad boundary with the Shepparton Formation of the Riverine Plains geomorphic unit.

The self-mulching clays of the unit are essentially end products of late-Pleistocene to Holocene aeolian redistribution of lacustrine sediments from inter-ridge corridors. These clays blanket the stranded beach ridges made up of Loxton-Parilla sandstone deposited as sands at a series of beaches marking stand-still stages of the retreating late Tertiary sea. Over 100 m of sediments deposited during much of the Tertiary period lie on pre-Cainozoic bedrock east of Lake Hindmarsh just north of the unit. The non self-mulching grey clays occur on the Pleistocene to Holocene floodplains and terraces of the Wimmera River (its tributaries and effluents) and on those of the Richardson and Avon rivers. Quaternary structural deformation resulted in the capture of the north flowing Yarriambiak and Dunmunkle creeks by the west flowing Wimmera River and in the redirection at Quantong of the latter north to Lake Hindmarsh. The onset of arid conditions in this period resulted in the relative abandonment of streams such as Corkers Creek and Two Mile Creek near Longerenong and in the formation of prior stream landscapes in the south and south-east of the unit. These conditions also favoured the development of a variety of aeolian landforms, which included source bordering sandsheets and longitudinal dunes, as occur on the stagnant alluvial plain south of Horsham, and near the Wimmera River.I Included also are lunettes which vary greatly in size and profile development. Small lake-lunette units, several hundred metres across, occur on the stagnant alluvial plain south of Horsham and on the undulating plains north of Horsham. Lunette deposits associated with Lake Buloke extend up to 6 km east of the lake bed.

Relief across most of the unit is very low, variation usually being within the range of 9-30 m. Surface levels of the gently undulating landscape north of Horsham vary from about 130 m on inter-ridge corridors to about 150 m on ridge crests. Distance between the ridge crests at Pimpinio and Jung is 26 km. Floodplains of the Wimmera River south and south-east of Horsham are generally below the 140 m contour. East of Horsham the 150 m contour is an approximate boundary delineating the marginally higher undulating plains to the north and the floodplains to the south-east of the unit. South and south-west of Horsham alluvial plains occur above the 150 and 160 m contours. Maximum slopes in the unit occur north-west of Horsham where levels fall from 150 m on ridge crests to 110 m near the Wimmera River within a distance of 3 km.

The main rivers in the unit are the Wimmera, the Richardson, its tributary the Avon, and in the north east, the Avoca. Rainfall on the Western Uplands outside the southern and eastern borders of the unit is the primary surface water source for these streams. With the exception of the Wimmera River which flows west to Quantong before turning north to Lake Hindmarsh, all streams including the Wimmera effluents (Dunmunkle and Yarriambiak creeks) flow north across the undulating plains to eventually discharge in salt lakes. On the undulating plains the streams are linear, fixed (showing little evidence of migration) and have a non-tributary pattern. On the floodplains in the south-east of the unit streams feeding into the Richardson River have uni-directional and integrated patterns. On a prior stream floodplain just north-east of Horsham some streams show a reticulate or anastomatic pattern. The Wimmera River tributaries Norton creek and Mackenzie River and the latter's tributary, Bungallaly Creek, are north flowing relatively inactive streams which cross an extensive (stagnant) alluvial plain to the south of and above the Wimmera River floodplain south of Horsham. This stagnant alluvial plain is gently sloping and rises from the 140 m contour at the northern boundary to the 170 m contour some 18 km to the south. Drainage of most of the unit is essentially internal and slow and in years of above average and record rainfall, as in 1973/74 and 1983, large areas become inundated. In 1983 11 000 ha flooded in the Richardson - Avon basin including areas of both the south-east floodplains and the undulating plains north to Donald.

Vertosols are the dominant Australian Soil Order (Isbell 1996) on both the relatively level floodplains in the south and on the gently undulating plains in the northern areas of the unit. Structural and consistence properties of the Vertosol surface soils on the alluvial plains differ from those on the undulating plains. On the alluvial plains surface soils are characteristically massive or epipedal and have a strong to very strong consistence. Subsurface sporadic bleaching may occur in these soils. On the undulating plains surface soils are characteristically self-mulching, have a weak to firm (friable) consistence and rarely have a sporadically bleached A2 horizon. Subdominant soils that also occur across the unit are Sodosols. Chromosols and Calcarosols have also been recorded.

Soil composition varies in different sub-units of the alluvial plains. On the higher level (stagnant alluvial) plains south of Horsham, the mostly grey, but also brown and yellow Vertosols are associated with brown Sodosols. In general, surface soils of both orders are slightly acid, have a low to very low salinity status, and are non-sodic. Upper subsoils are neutral to slightly alkaline, have a low salinity status and are sodic.

On the lower level floodplains, the dominantly grey Vertosols are associated with mainly red Sodosols. Surface soils of these Vertosols are usually slightly alkaline, have low salinity status and are non-sodic. Sub-soils are slightly to moderately alkaline, have salinity levels varying from very low to medium and are sodic. Deep subsoils are slightly to strongly alkaline, have high to very high salinity status and are strongly to very strongly sodic. In general, surface soils of the red Sodosols are neutral to moderately acid, have low to very low salinity levels and are non-sodic. Subsoils are moderately to strongly alkaline, have a medium salinity status and are strongly sodic. Deep subsoils are strongly to very strongly alkaline, have high to very high salinity levels and are strongly to very strongly sodic.

Dunes, interdune swales and sandsheets (the Lowan Sands) form minor landscape components within the alluvial plains. Red, brown and grey Sodosols occur on dunes and sandsheets. Surface soils are slightly acid, have very low salinity level and are non-sodic. Subsoils are slightly alkaline, have low to medium salinity levels and are strongly sodic. Deep subsoils are moderately alkaline, have medium salinity status and are very strongly sodic.

Grey Vertosols are strongly dominant on the plains and broad corridors between and on the gentle slopes of the subdued north-west to south-east ridges. This array of soils has been referred to as the ‘Kalkee’ association. Surface soils are moderately alkaline, have a low salinity status and are non-sodic. Subsoils are strongly alkaline, have a medium salinity status and are sodic. Deep subsoils are strongly alkaline, can have very high salinity status and are very strongly sodic. In some locations on the plains, there may be as little as 1 m of clay above sandstone. Grey Sodosols may occur on some of the local small depressions, which exist on the plains. On the upper slopes and crests of the ridges, red Sodosols and occasionally brown Chromosols occur together with the grey Vertosols. This array of soils has been referred to as the ‘Murra Warra’ association. The texture contrast soils are slightly acid, have low salinity levels and are non-sodic. Subsoils are slightly alkaline, have very low salinity levels and are sodic. Deep subsoils are very strongly alkaline, have medium salinity status and are sodic. Red Sodosols may lie directly on sandstone that may occur as shallow as 75 cm in ridge areas.

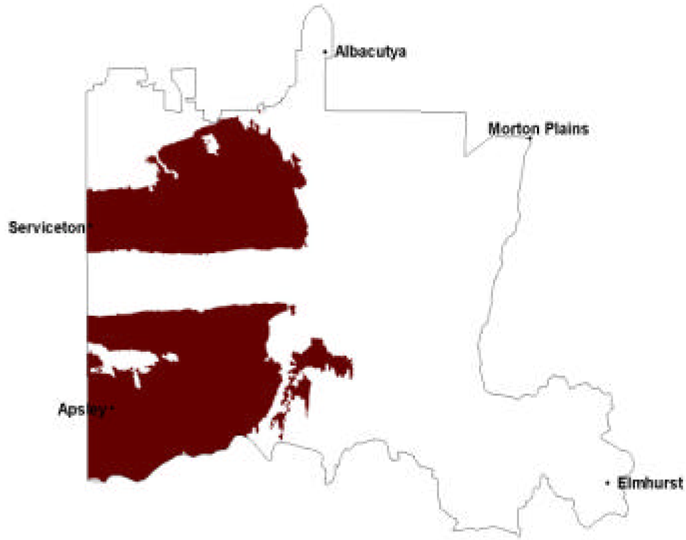
Soils on gently to moderately undulating plains areas in the north-east of the unit, north and north-west of Charlton, are dominantly red Sodosols. Surfaces of these soils are slightly alkaline, have low salinity status and are sodic. Subsoils are strongly alkaline, have medium salinity status and are also sodic. Deep sub-soils are very strongly alkaline, have a very high salinity status, and are very strongly sodic (‘Charlton’ association).

Although almost entirely cleared for primary production, it is considered that the original broad vegetation type was a grassland-woodland complex also described as a savannah woodland sub-formation. A local, near Horsham, more detailed reconstruction described five woodland communities each dominated by a different tree species and one grassland community. Vegetation changes were related, to some extent, to soil variation. Black box woodland occupied lake beds, river frontages and river flats. The ‘Buloke’ association was characteristic of much of the undulating plains landscape with some spear and wallaby grassland areas associated with friable grey clay soils.

Cereal cropping has been the dominant farming enterprise across most of the western two-thirds of the undulating plains. On the floodplains and alluvial plains and in areas east of Lake Buloke grazing for wool production has been a significant enterprise. These latter mixed cropping and grazing areas are also those with smaller proportions of self-mulching clays and increased proportions of non self-mulching grey clays and red texture contrast soils. Surface soil features which are significant in terms of reducing plant performance and cereal production include the massive and epipedal condition and the strong (non-friable) consistence of the floodplain Vertosols and the hardsetting condition of many of the Sodosols.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Bangerang prior stream plains | Plains with prior streams | 84 |
| Beulah plains | Gently undulating plains | 217 |
| Brim undulating rises | Gently undulating rise | 60 |
| Donald lake-lunettes | lake-lunette system-cluster | 19 |
| Dooen eroded plain | Eroded plain | 58 |
| Horsham lake and lunettes | lake and lunette | 37 |
| Horsham lake-lunette cluster | Lake-lunette cluster | 5 |
| Horsham township | Township | 12 |
| Jerro eroded ridges and slopes | Eroded ridge and slopes | 118 |
| Kalkee plains | Gently undulating plains | 778 |
| Kalkee plains 2 | Gently undulating plains | 245 |
| Kellalac eroded ridge crests | Eroded ridge crest | 26 |
| Kiata rises | Gently undulating rises | 44 |
| Murra Warra East gentle rises | Moderately undulating plains | 540 |
| Murra Warra West gentle rises | Gentle rises | 577 |
| Riverside level plains | Level plain | 3 |
| St Helens gentle plains | Gentle plain | 321 |
| Vectis undulating rises/low hills | Undulating rises and low hills | 14 |

## 5.5 Ridges with sand, and flats




This geomorphic unit is located in western Victoria and extends into South Australia. The unit is spatially subdivided with the Little Desert separating the northern (Nhill) area from the southern (Goroke) area.

The unit can also be divided into components (units at the third tier level) of ridges (unit 5.5.1) and intervening flats (unit 5.5.2). This unit is clearly bound by siliceous dunefields to the north (unit 5.2), the Douglas Depression system (unit 5.3.3) to the east and a less clear boundary to the Dundas Tableland (unit 2.3) to the south, close to the Glenelg River.

The predominant landforms are a series of parallel ridges orientated to the NNW/SSE with intervening depressions or flats. The ridges may vary in elevation, relative relief and morphology such that some are a complex of slope segments with higher elevation depressions while others have a simple convex form from one flat to the next. The major ridges can have a width of over 5 km with at least the same width for the adjoining flat, the smaller ridges are narrower, closer to 2 km in width. Slope also varies, with slopes of the order of 5% or less on most ridges but 8% on the larger ridges, particularly in the northern section; the southern section having more subdued relief and affected by more recent geological events as well as climate.

The drainage pattern is strongly influenced by the pattern of ridges and flats with some swamps and lakes occupying the flats, particularly the southern area, where the landscape is more subdued (but slightly higher elevation) and the climate moister.

The dominant geology is that of Tertiary and Quaternary material laid down as part of the Murravian Basin. The parallel ridges, consisting of Parilla Sand are former strandlines of the retreating Tertiary sea with the flats developing from the intervening lagoonal deposits with the Western Uplands thought to remain above sea level. The age of the retreating shorelines is thought to be between 2 and 6Ma, the majority of this geomorphic unit being about 3-4 Ma old (Kotsonis 1996).

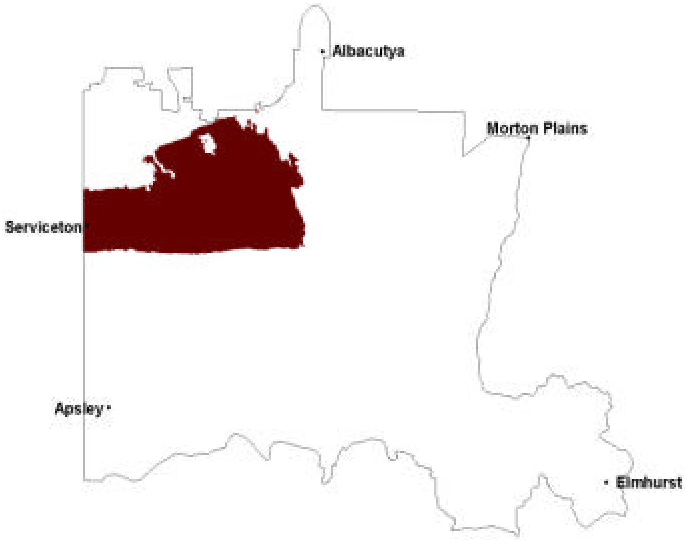
Subsequently windblown deposits of fine calcareous and saline material known as the Woorinen Formation blanketed the area in the early Quaternary period (also known as parna). The most recent deposition is that of the coarser unconsolidated pale sand known as Lowan Sand which is the major constituent of the Little Dessert and also caps many ridges in the southern area. These phases of deposition are thought to be coincident with a climatic change, the Woorinen Formation requiring a dry climate, while a wetter period would have been required for the lagoonal and lacustrine deposits.

Tectonic movement is thought to be a reason why the course of the Glenelg River does not follow the exact edge of the Dundas Tableland to the south and may have influenced the apparent deflected strandlines that seem visible by remote sensing on the adjoining tableland (Joyce 1999).

Soils types include red sodic texture contrast soils (Sodosols) in the northern area developed on the rises, with mottled Sodosols in the southern area and black cracking clays (Vertosols) in the depressions (swales) of northern and southern areas. Pale sandy soils (Rudosols and Podosols) occur on the Lowan Sand in the south and some reworked areas of exposed and heavily ferruginised Parilla Sand.

Yellow gum occupies the ridges and black box is vegetataion typical of the flats. The cracking clay soils are cropped as well as the red sodic soils, and the sandy soils are often forested (plantations).

### 5.5.1 Prominent ridge tops with remnant aeolian sands and orientated swales with lakes and lunettes (north of Little Desert – Diapur, Kiata)




This unit is located in western Victoria, clearly bounded by the Little Desert to the north and the low plateau (Dundas Tableland) to the south. The South Australian border is the artificial western boundary and the Wimmera River Valley (Lowan Salt Valley) and the Douglas Depression comprise the eastern boundary.

This unit is dominated by a series of parallel and subparallel ridges orientated NNW/SSE, interspersed with similarly aligned valleys or swales. This pattern is still discernible in the siliceous dunefield units (5.2) to the north. This landform pattern is not as distinct in this unit as compared with north of the Little Desert, with the relative relief of the ridges ranging from 10 to 40 m. The ridges have an amplitude of 2 km and slopes up to 5%.

The intervening valley floors may extend to plains in the west (Apsley) and nearer the eastern boundary. These valley floors are dominated by lagoonal deposits, which can be quite shallow as well as the many lakes, swamps and depressions.

The ridges consist of Parilla Sand ferruginised at the surface and exposed on the larger ridges, while Lowan Sand Formation siliceous sandy material covers most of the smaller ridges and adjoining slopes; a result of reworking of the Parilla Sand. The valley floors have younger lagoonal deposits consisting of expansive (cracking) dark organic clays, which may be quite shallow at their edges, as well as some texture contrast soils on alluvial rather than aeolian deposits.

These plains of Quaternary lacustrine and aeolian sediments is part of a NNW/SSE orientated terrain surrounded by associated rises/ridges and other ridge/depression landscapes. Drainage is strongly aligned to the terrain with little surface expression apart from local depressions, including swamps and lakes. Sandy surfaced sodic texture contrast soils (Sodosols) and sandy soils (Rudosols and Tenosols) are generally acidic and occur on the Parilla Sand exposures and the Lowan Sand terrain, while sodic (Sodosols)and non-sodic texture (Chromosols) contrast soils occur on the smaller ridges and lower. Grey and black cracking clay soils (Vertosols) formed on lagoonal deposits dominate the swales and valley floors.

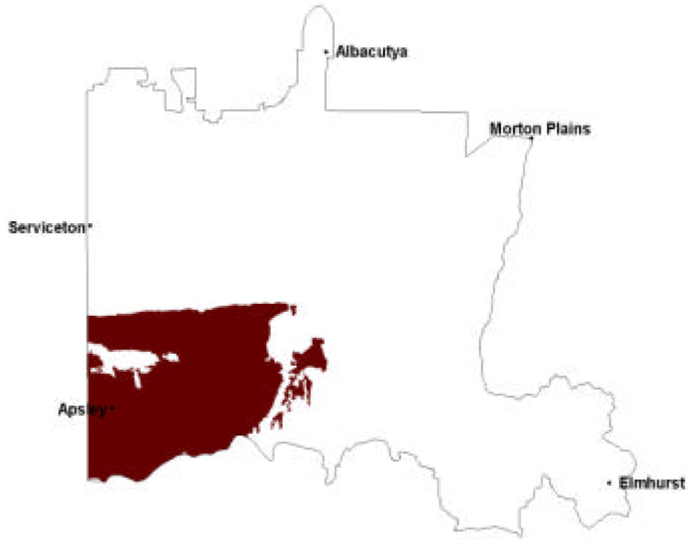
Woodland and mallee vegetation communities such as Low Rises Woodland, Heathy Mallee, Red Swale Mallee, Ridged Plains Mallee, Plains Woodland, Parilla Mallee and Shallow Sands Woodland dominate remnant vegetation on sandy rises and dunes. Other vegetation communities recorded include Plains Savannah, Plains Grassland and Sandstone Ridge Shrubland. The main vegetation communities of the former stranded beach ridges include Shallow Sands Woodland, Sandstone Ridge Shrubland, Ridged Plains Mallee, Parilla Mallee and Low Rises Woodland. Smaller extents of Heathy Woodland, Lowan Sands Mallee, Dunefield Heathland, Plains Woodland and Plains Savannah have also been recorded. Plains Savannah and Ridged Plains Mallee are the most expansive remnant vegetation communities found mostly on clay soils and plains. Areas of other vegetation communities such as Lignum Swampy Woodland, Plains Woodland, Sandstone Ridge Shrubland, Shallow Sands Woodland, Parilla Mallee, Low Rises Woodland and Heathy Mallee are also found. Lignum Swampy Woodland, Plains Woodland, Red Gum Wetland and Seasonally Inundated Shrubby Woodland are found in wetter areas of the landscape.

Sheet erosion is relevant to any sloping terrain with water repellancy as an associated issue in this unit. Wind and gully erosion is a land degradation issue particularly relevant to the larger ridges. Water repellency is an issue on the sandy surfaced soils with some organic matter, particularly where surface soil horizons are shallow. Waterlogging may be an issue on the valley floors depending on rainfall events, as rainfall increases southward.

| Soil-landform unit | Unit description | Area (km$^2$) |
|---|---|---|
| Broughton plains | Gently undulating plain | 69 |
| Diapur ridge | Undulating stranded beach ridge | 648 |
| Kiata rises | Gently undulating rises | 519 |
| Lillimur South clay plains | Self mulching clay plains | 127 |
| Lorquon undulating plains | Gently undulating plain | 784 |
| Nhill lake & lunettes | Lake | 73 |
| Perenna undulating sand plains and rises | Gently undulating sand plains | 179 |
| Servicetown North limestone rises | Limestone rises | 5 |
| Woorak clay plains | Grey clay plain | 539 |

Figure 17 Former stranded beach ridges (rises) with swales orientated NNW/SSE near Boyeo

## 5.5.2 Low ridge tops with remnant aeolian sands and oriented swales with lakes and lunettes (south of Little Desert – Kowree, Goroke)




This unit is located in western Victoria, clearly bounded by the Big Desert to the north and the little Desert to the south. The South Australian border is the artificial western boundary and the Wimmera River Valley (Lowan Salt Valley) is the eastern boundary. Similar terrain is found to the south of the Little Desert.

This unit is dominated by a series of parallel and subparallel ridges orientated NNW/SSE, interspersed with similarly aligned valleys or swales. This pattern remains discernible in the siliceous dunefield units (5.2) to the north and south. This landform pattern is at its most distinct in this unit with the relative relief of the ridges ranging from 10 to 60 m. The major ridges (Diapur/LawloitRange/Propodollah) have an amplitude of about 5 km with slopes of up to 8%, while the smaller ridges have an amplitude of 2 km and slopes up to 5%. The larger ridges have a complex of components including elevated swales/valleys.

The intervening valley floors may extend to plains in the west and nearer the eastern boundary. These valley floors are dominated by lagoonal deposits, which can be quite shallow as well as the occasional swamp. There is the occasional sandy dune.

The ridges consist of Parilla Sand ferruginised at the surface and exposed on the larger ridges, while Woorinen Formation calcareous sandy clay regolith material (parna) covers most of the smaller ridges. Reworking of the Parilla Sand crests has resulted in a younger unconsolidated silceous sand (Lowan Sand) on the crests and on the valley floors/plains. The valley floors have younger lagoonal deposits consisting of expansive (cracking) dark organic clays, which may be quite shallow at their edges.

This plains of Quaternary lacustrine and aeolian sediments is part of a NNW/SSE orientated terrain surrounded by associated rises/ridges and other ridge /depression landscapes. Drainage is strongly aligned to the terrain with little surface expression apart from local depressions, including swamps and lakes.

Sandy surfaced sodic texture contrast soils (Sodosols) and sandy soils (Rudosols and Tenosols) are generally acidic and occur on the Parilla Sand exposures while sodic (and calcareous) red texture contrast soils occur on the Woorinen Formation material, mainly on the smaller ridges. Grey and black cracking clay soils (Vertosols) formed on lagoonal deposits dominate the swales and valley floors.

Vegetation is dominated by woodland and wetlands on expansive plains including Plains Woodland, Shallow Sands, Damp Sands Herb-rich Woodland and Red Gum Wetland. Plains Grassy Woodland is found mostly on freely draining soils. Lunette Woodlands, Heathy Woodland, Cane Grass Wetland, Aquatic Herbland, Shallow Sands Woodland and Escarpment Shrubland are also found on these plains. On sandy dunes and rises (ridges), Shallow Sands Woodland, Damp Sands Herb-rich Woodland, Sand Heathland, Plains Grassy Woodland, Low Rises Woodland and Sandstone Ridge Shrubland are prominent. In the poorer drained swales, swamps, depressions and associated plains, Lignum Swampy Woodland, Freshwater Lake Mosaic, Dune Soak Woodland, Brackish Wetland, Plains Savannah, Shallow Sands Woodland, Plains Woodland, Drainage-line Woodland, Heathy Woodland, Brackish Lake Mosaic, Lignum-Cane Grass Swamp Drainage-line Woodland and Red Gum Wetland occur. Yellow box is the dominant primary vegetation on the ridges with some *Casaurinas* also occuring. The valley floors are dominated by black box as their primary vegetation.

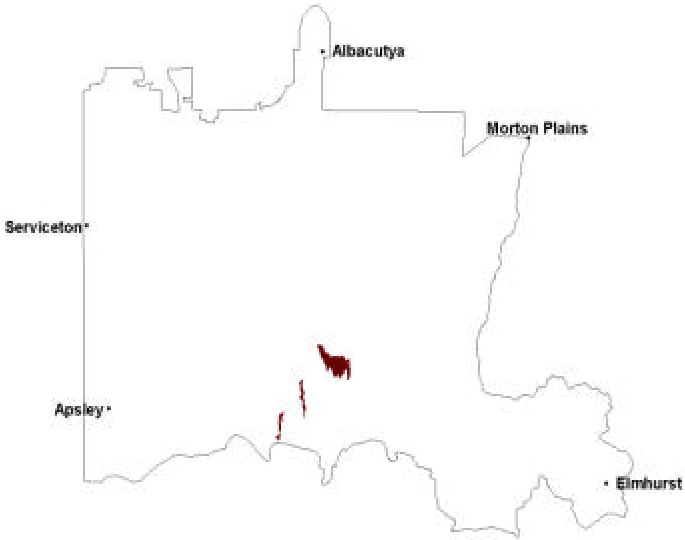
Sheet erosion is relevant to any sloping terrain, with water repellancy as an associated issue in this unit. Wind and gully erosion is a land degradation issue particularly relevant to the larger ridges. Water repellency and infiltration are issues on the red texture contrast soils particularly where surface soil horizons are shallow. Waterlogging may be an issue on the valley floors depending on rainfall events.

The Parilla Sand deposits provide roading material and are a source of heavy minerals (Campbell et al. 2003).

| Soil-landform unit | Unit description | Area (km$^2$) |
|---|---|---|
| Apsley plains | Plain | 441 |
| Benayeo gilgai plains | Plain | 191 |
| Diapur ridge | Undulating stranded beach ridg | 25 |
| Edenhope undulating plains | Plains with subdued ridges | 196 |
| Fairview plains | Gently undulating plains | 20 |
| Goroke plains and rises | Plain with prominent ridges | 537 |
| Horsham lake and lunettes | Lake and lunette | 4 |
| Horsham lake-lunette cluster | Lake-lunette cluster | 4 |
| Kowree undulating sand plains and ridges | Undulating sand plain and ridges | 1059 |
| Kybybolite plains | Plains | 40 |
| Langkoop clay plain | Clay plain | 40 |
| Merryvale lakes and ridges | Lakes and ridges | 14 |
| Minimay plains | Gently undulating plains | 41 |
| Mosquito Creek swampy sand plains | Swampy sandplain | 104 |
| Neuarpur undulating plains | Plains with subdued ridges | 172 |
| Nurcoung plains | Plains | 139 |
| Powers Creek sand plains | Gently undulating sand plains | 79 |
| Ullswater plains and rises | Plains with parallel ridges | 609 |
| West Wimmera wetlands | Lake | 129 |

Figure 18 Series of lakes and swamps in swales with sand dunes masked by remnant vegetation near Karnak

### 5.5.3 Prominent ridges with eroded ferruginized northern spurs (south of the Lower Norton Wimmera Bridge - Darragan)




This unique unit of nearly 9500 ha occurs in the WCMA region of western Victoria. It lies south of the original small Quantong Irrigation Settlement and the Wimmera River. It is immediately south of the road junction at Lower Norton, east of the East Natimuk-Noradjuha Road and west of Norton Creek. Two roads traverse the unit, the Lower Norton- Noradjuha Road and the more easterly Lower Norton- Toolondo Road. This latter road crosses the centre of the unit for about 7 km.

Prominent ridges are clearly bounded by the terraced land of the Wimmera River (unit 4.1.1) and the alluvial floodplain (unit 4.2.2) that lie to the north and north-east of this unit. The alluvial apron of stagnant outwash fans (unit 4.3) lies to the south-east and south-west with eastern extents of the low ridge tops with remnant aeolian sands and oriented swales with lakes and lunettes (unit 5.5.2) occurring along its western extent. Two other elongated units exist further south-west that represent clearly defined (pronounced from radiometric signatures) stranded beach ridges that have been strongly ferruginised.

Within the unit geomorphic processes are unique in that they have resulted in a topography and set of landform elements not seen elsewhere in the region. Erosion by the west flowing Wimmera River has resulted in a sequence of seven sets of spur-valley units (series of parallel and subparallel ridges are orientated NNW/SSE) along the northern and north-eastern boundaries of the unit. This erosion has exposed underlying Parilla Sand cutting through the old Neogene/Quaternary plain to meet the base level of Wimmera River to the north.

The unit occurs mainly between the 130 m and 150 m contours. The elongated rolling rises comprise a sequence of landform elements reflecting truncation of the ridges by the Wimmera River in the north, and lateral erosion of the ridges which is less effective to the south where these ridges become more subdued within the landscape towards the Dundas Tableland. Relative relief is about 10–15 m from the old plain surface (ridge crests) to the Wimmera River floodplain Side slopes of the spurs are gently inclined (undulating) averaging 2-5%, with level to very gentle flats typical of the swales. Ridges slope along the north-south axis of their crests average about 1%. Narrow valleys between the spurs contain at least five unnamed unidirectional stream channels, which under flood conditions may flow north across the floodplain to join the Wimmera River. To the south the land surfaces continue to rise to above the 160m contour within the adjacent Horsham South flat plains.

Deeply weathered texture contrast soils are dominant across the unit. Sodosols occur on the crests and slopes of the ridges with red and brown Sodosols on crests and red Sodosols on slopes. Sodosols with cemented (ferruginised) subsurface horizons and mottled subsoils occur on inter-ridge corridors. Ironstone gravels in varying amounts are commonly present both as a surface pavement throughout soil profiles. Varying amounts of soft and hard carbonate segregations are often present in subsoils with cracking clays confined to lower drainage depressions and flats. Bleached Tenosols occur on terrace landform elements along inter-ridge corridors.

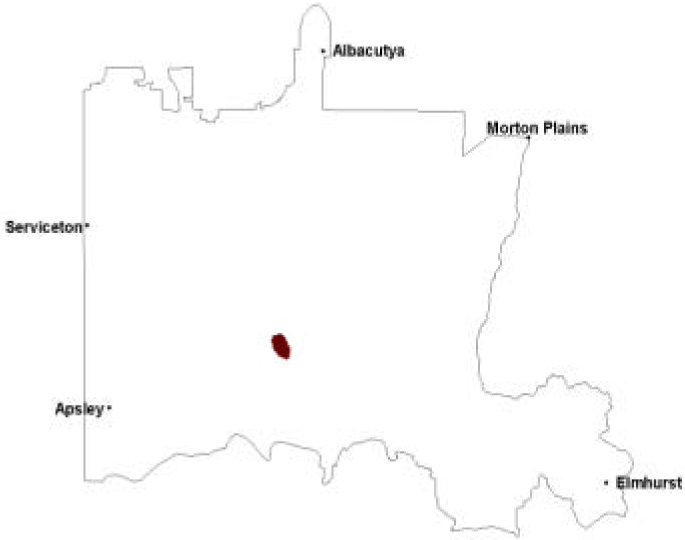
Dominant woodland remnant vegetation includes Heathy Woodland, Riverine Chenopod Woodland, Grassy Woodland, Creekline Sedgy Woodland, Plains Woodland and Shallow Sands Woodland with Grey Box and Yellow Gum found along narrow valley floors. Sandstone Ridge Shrubland is also found along ridges and rises in the landscape.

Sheet and rill erosion provide source material for the Wimmera River floodplain and terraces. Soils are prone to compaction due to hardsetting surfaces that benefit from organic matter contributions to improve soil structure. Land use is variable between dryland cereal cropping, sheep and cattle grazing and occasional intensive industries (e.g. viticulture).

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Darragan rolling rises | Rolling rises | 92 |

Figure 19 View is to the north-east across a corridor to a ridge about 0.8 km in the distance

## 5.6 Hills and low hills (Mount Arapiles)




A number of topographically significant and materially different features appear within the North West Dunefields and Plains as inliers. The major inliers include the largest inlier, Mount. Arapiles and associated outlier (Mitre Rock,) as well as Mount. Jeffcott and lower weathered Palaeozoic sediments often subsumed by surfical deposits. This is a similar category to that within the Northern Riverine Plains (unit 4.4).

The Mount Arapiles complex is to the west-north-west of the Grampian Ranges, relatively square in plan view with an area of approximately 15 km$^2$. Slopes are characterised by steep to precipitous segments and a relatively flat summit at about 300 m elevation with a striking mesa at 369 m. The mountain itself is unlike the sharper strike ridges and valleys of the Grampian Ranges while composed of similar material and geological age. Mitre Rock occurs as an isolated monadnock of Grampians sandstone to the north of Mount Arapiles. Mount. Arapiles is bound by the Douglas Depression (unit 5.3.3) to the west, north and south, as well as ridges with sand and flats (unit 5.5.2) to the south-east and clay plains (unit 5.4) to the east.

Mount. Arapiles is made up of resistant Grampians sandstone with the Douglas Depression diverted around it, indicating some form of structural control. It is abutted by stranded beach ridges, and a marine cut platform at its base is evident as part of the transgression/regression cycle of the Tertiary sea.

Regolith development is correlated with landscape position with the steeper stripped slopes having relatively shallow depth to bedrock and occasional rock outcrop. Broader crests may have greater regolith development along with lower, gentler slopes that are colluvial in origin. Drainage is best defined on surrounding gently inclined plains and rises that feed Mitre Lake to the north along with other swamps of the Douglas Depression.

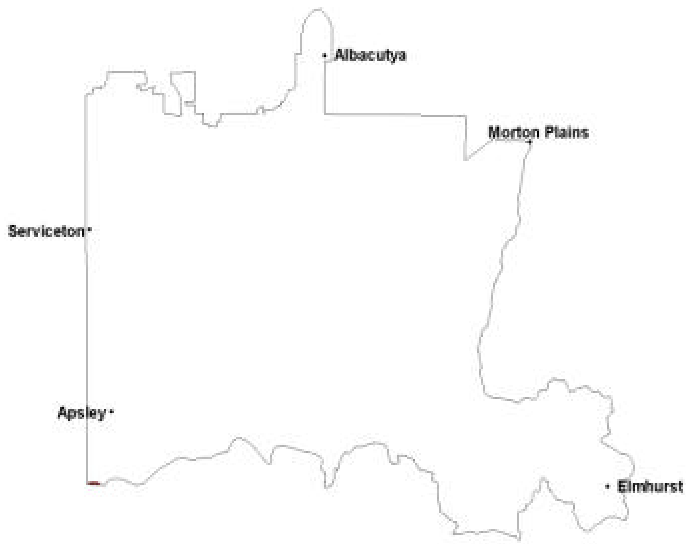
Soil types tend to be Tenosols and Kandosols that are sandy throughout, with Rudosols on rocky areas and occasional sodic texture contrast soils (sodosols) on the lower slopes. These texture contrast soils can often be calcareous, while some are red and stony reflecting pedogenesis from surrounding Parilla Sand ridges that abut the prominent sandstone outcrop of Mount Arapiles. Soils at higher elevations tend to have acidic profile trends, while those in a lower topographic position may be alkaline.

The main vegetation communities include Plains Woodland and Shallow Sand Woodland. Smaller areas of shrubland, such as Rocky Outcrop Shrubland and Sandstone Ridge Shrubland, as well as Heathy Woodland and grasslands are also found in this area.

The steep to precipitous slopes of Mount Arapiles attract rock climbing enthusiasts from around the globe. The coarse sand nature of much of the surface soil/regolith has a high potential for sheet erosion, where fines can be easily disaggregated and transported.

| Soil-landform unit | Unit description | Area (km$^2$) |
|---|---|---|
| Arapiles steep hills | Steep hills | 46 |

# 6 Western Plains

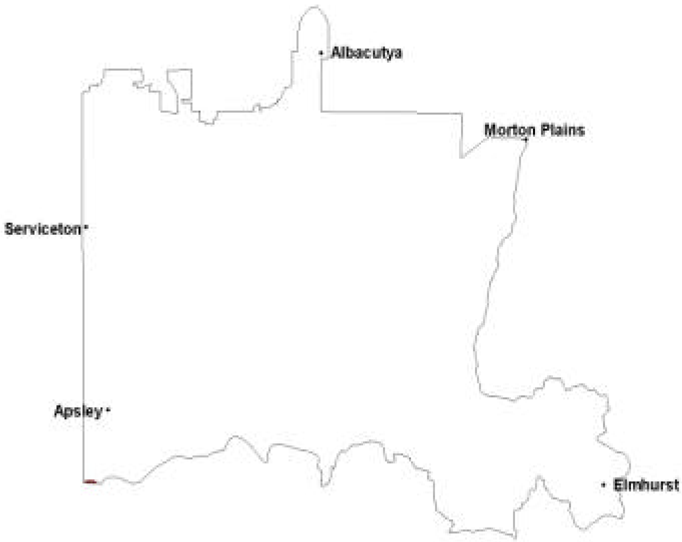



The WCMA region lies on the northern extent of the Victorian Western Plains, comprising undulating plains formed on both volcanic and sedimentary rocks. Landscapes of this physiographic unit are formed on some of the youngest rocks of the region which are more common further south of the WCMA boundary.

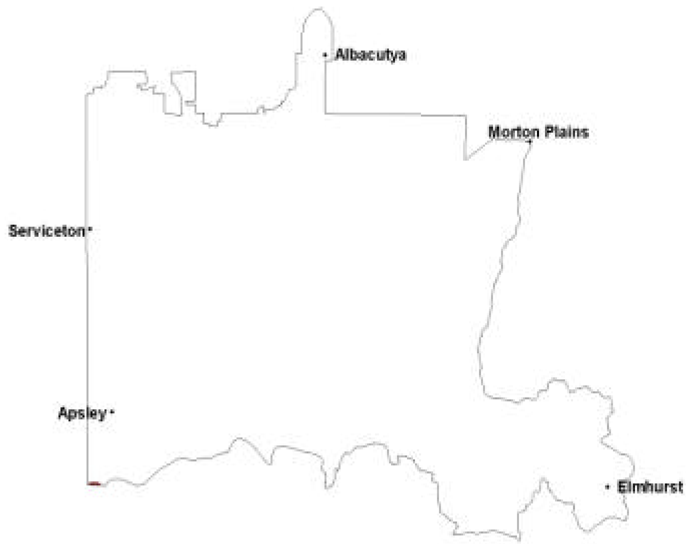
Soils on the Western Plains reflect the underlying lithology and age of the rocks. The youngest landscapes — the stony rises — have skeletal uniform or gradational soils, whereas the older basalts have developed deeper soils varying from friable gradational to strongly texture contrast soils. The friable, finely structured brown gradational soils developed on the scoria represent some of the most valuable cropping country. The soils developed on the Pliocene sand plains are often sandy, sometimes ferruginised or podsolic (sands with coffee rock or sand over clay) soils. Further south on the marls and limestones, the soils vary from clay-rich (medium or heavy textured) gradational to strongly texture contrast soils and generally heavy (uniform) clays.

## 6.2 Sedimenatry plains (unconsolidated sedimentary deposits)

The sedimentary plains mainly comprise the marine sands deposited by the retreating Pliocene sea and the exposed underlying sediments of the Bridgewater Formation including Gellibrand Marl and Port Campbell Limestone. The sand plains also appear as 'windows' within the volcanic plains, where they were not covered by lava from the Newer Volcanic eruptions.



## 6.2.1 Plains with depositional ridges (Kanawinka)




Located in the very south-west corner of the WCMA region is the Kanawinka sand plains and dunes soil-landform unit. More pronounced and quite extensive in the south-west of the Glenelg Hopkins CMA region, the sand plains and dunes recognise a change from the low ridge tops with remnant aeolian sands and oriented swales with lakes and lunettes geomorphological division (unit 5.5.2) to this landscape. While the surface expression in terms of topography, soils and vegetation is extremely similar, this geomorphology reflects a transition to later sediments deposited further south-west into Victoria and South Australia.

Sandsheets and dunes of this landscape include dunes with crests, slopes and associated plains with little relief (approximately 5 m) and poorly defined surface drainage. Occurring between 120 and 140 m, slopes are level to gently inclined and dominated by aeolian sands and silts. Plains and swamps are also prominent with swamp beds and sandsheets common in this rather subdued plains landform.

Parent material comprises Neogene marine sand and silt (Parilla Sand), Quaternary aeolian dune sand (Lowan Sand) and paludal silt and clay of swamp deposits. Underlying Parilla Sand is strongly ferruginised at the surface where infrequently exposed on areas of slight dissection. Reworking of the Parilla Sand has resulted in the younger unconsolidated siliceous sand (Lowan Sand) developing as sand plains and dunes. Swamps with younger lagoonal deposits consisting of expansive (cracking) dark organic clays also occur.

Acidic sandy soils with and without pans (Tenosols and Podosols) are found on dunes and sporadically on sandy plains where sodic brown, yellow and grey texture contrast soils (Sodosols) are dominant. Wind erosion is likely where dunes lack significant vegetation coverage. Cracking clay soils (Vertosols) are associated with the swamps and plains where poorly drained.

Remnant vegetation is largely either Plains Grassy Woodland or Damp Sands Herb-rich Woodland, Plains Swampy Woodland orAquatic Herbland Mosaic vegetation communities. Heathy vegetation comprises brown stringybark, yellow gum, prickly tea-tree and pink gum with manna gum infrequent on swamps.

| Soil-landform unit | Unit description | Area ($km^2$) |
|---|---|---|
| Kanawinka sand plains and dunes | Sandsheets and dunes | 4 |

# 3 Soil-landforms

Across the WCMA region a number of land and soil surveys exist that have been carried out by government organisations including the Soil Conservation Authority (SCA), Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the former Department of Agriculture and Rural Affairs (now known as the Department of Primary Industries (DPI)). These studies have used different scales for specific purposes.

For example an agricultural and horticultural land suitability for the Shire of West Wimmera at 1:100 000 (Baxter, Williamson & Brown 1996) focused on providing ‘information for broad scale planning’ by defining the ‘capability of the different types of land to support various land uses’.

Studies at 1:100 000 scale aim to provide the reader with base information to ‘examine the nature and interactions of features of the natural environment’ while focusing on ‘sustained productivity of the land, its use and management’ (Pitt 1981). As a result, information presented by these previous studies (Table 1) is varied in detail. This posed a primary constraint in the development of consistent and seamless map coverage for the entire WCMA region at 1:100 000 scale. This is further discussed in Section 3.2 (Map creation).

## 3.1 Concept and definitions

Mapping of environmental features or landscape attributes can have decidedly different terminology and accompanying definitions. Terms such as landsystems (‘areas of land each with a characteristic pattern of the environmental variables, climate, geology, topography, soil and vegetation’) and terrain (‘land uniquely defined in terms of topography, underlying lithological and structural characteristics, and soil and vegetation characteristics) have been encountered as part of this study.

The definition of mapping units is based upon an ecosystem concept in which several land features are integrated (defined in previous terms and definitions). Climate, geological material, landform and soil are each considered because they affect the inherent properties of the land, and its response to management (Charman & Murphy 1991). In this study the term ‘soil-landform’ is used to describe the map units. The soil-landform unit is an association of a specific landform pattern and its accompanying soils while considering other environmental variables in delineating areas of homogenous soil-landform relationships. At the scale of mapping in this study the soil-landform unit itself is made up of land components or elements. Where possible we have defined the specific associations that exist between soils and land components within a soil-landform. Some of these map units are simple, having only one land component (e.g. some of the larger swamp units or simple plains), whereas others are more complex having several components.

## 3.2 Map creation

In generating a soil-landform map for the WCMA region, a number of factors were considered in the editing and compilation phases. These factors include which studies to include or use, and issues with studies and datasets used in derivation of unit boundary linework.

**Issues arising from incorporation of existing studies into mapping**

For the WCMA region, a number of soil and land related studies and surveys have been published (Table 1). These soil and land surveys have varying spatial coverages and were created for a number of purposes and this is reflected in the style and contents of the survey reports. In total, eleven soil and land surveys have been used in assembling the soil-landform units for WCMA region. These surveys are briefly described in Table 1 according to their author, year of publication, responsible organisation, mapping scale and reference locality. Brief comments for all surveys regarding their functional role in the creation of the soil-landform map is discussed further in Table 2 with many of these descriptions sourced from Robinson et al. (2003c).

Table 1 Existing soil and land surveys within the WCMA region used in mapping the catchment

| | Survey title | Author | Year | Organisation | Reference locality | Scale |
|---|---|---|---|---|---|---|
| 1 | Agricultural and horticultural land suitability for the West Wimmera Shire | Baxter, Williamson and Brown | 1996 | Department of Natural Resources and Environment | Shire of West Wimmera | 1:100 000 |
| 2 | Lowan land inventory assessment | Imhof, Rees and Thompson (Williamson ed.) | 1997 | Department of Natural Resources and Environment | Shire of Lowan | 1:100 000 |
| 3 | Landform mapping and recharge estimations for the Old Dimboola Shire | Muller and Hocking | 2002a | Department of Natural Resources and Environment | Old Dimboola Shire | 1:100 000 |
| 4 | Landform mapping and recharge estimations from Horsham to Dimboola | Muller and Hocking | 2002b | Department of Natural Resources and Environment | Old Dimboola Shire | 1:100 000 |
| 5 | Soil association of the Horsham mapsheet | Badawy | 1977a | Department of Agriculture | Horsham | 1:100 000 |
| 6 | Major agricultural soils of the Wimmera Irrigation Area | Martin et al. | 1996 | Department of Natural Resources and Environment | Wimmera Irrigation area | 1:100 000 and 1:35 000 |
| 7 | Soils of the eastern Wimmera | Badawy | 1984 | Department of Agriculture | Charlton, Donald, Rupanyup | 1:100 000 |
| 8 | Land inventory of the Wimmera Systems and Rocklands Water Supply Catchment | White et al. | 1985 | Department of Conservation Forest and Lands | Upper Wimmera catchment | 1:100 000 |
| 9 | A study of land in the Grampians area | Sibley | 1967 | Soil Conservation Authority | Grampians Ranges | 1:250 000 and 1:100 000 |
| 10 | A reconnaissance survey of the soils of the Shire of Kowree, Victoria | Blackburn and Gibbons | 1956 | CSIRO | Kowree | 1:250 000 |

Continued next page

Table 1 continued

| | Survey title | Author | Year | Organisation | Reference locality | Scale |
|---|---|---|---|---|---|---|
| 11 | Natimuk | Maher and Martin | 1990 | Department of Agriculture and Rural Affairs | Natimuk | 1:100 000 |
| 12 | Landscapes and soils of the Goroke area | Maher and Martin | 1990 | Department of Agriculture and Rural Affairs | Goroke | 1:100 000 |

Note that all soil and land surveys are provided as appendices accessable via the CD-ROM as reports and/or maps.

Table 2 Functional role of soil surveys in creation of the soil-landform map for the WCMA region

| Survey title | Functional role in map creation |
|---|---|
| Agricultural and horticultural land suitability for the West Wimmera Shire | The maps and accompanying report provided a basis for soil-landform mapping in the west of the Wimmera region. Landform information is of a particularly high standard using aerial photography interpretation procedures. Soil pit data was collected as part of the project, however inspection site data is missing. The survey had some inconsistencies with overlapping surveys including *A reconnaissance survey of the soils of the Shire of Kowree, Victoria* and *Landscapes and soils of the Goroke area.* |
| Lowan land inventory assessment | This land assessment report describes nine mapping units and has been used as a mapping base with little refinement over the Lowan Shire area. Soils information that relates to units is quite detailed and informative with toposequence schematics provided. Mapping with the neighbouring surveys was consistent as the earliest survey (West Wimmera) was effectively continued to the east. |
| Landform mapping and recharge estimations for the Old Dimboola Shire | Mapping builds upon the soil-landform assessment of the Lowan land inventory assessment and continues mapping further east past the Wimmera River. The units were generated for a hydrogeological assessment, however they are extremely similar in nature to that of the Lowan shire mapping. Soil attribution and point data is absent here and therefore some of the units have been refined, deleted or added to in the development of a consistent map base. No neighbouring mapping exists to the east, placing a lower confidence on units along the eastern extent. |
| Landform mapping and recharge estimations from Horsham to Dimboola | Mapping builds upon the soil-landform assessment of the Lowan land inventory assessment the recharge estimation landform mapping further north (*Landform mapping and recharge estimations for the Old Dimboola Shire*). The units were generated for a hydrogeological assessment and are likely to exhibit a higher degree of uncertainty than mapping in the north. Mapping also has numerous overlaps with the Natimuk soil-landform mapping and new mapping generated as part of this project for the Horsham mapsheet. Little mapping has been preserved through new mapping as a result. |
| Soil association of the Horsham mapsheet | The mapping units used are strictly soil association units and don't necessarily conform to landforms. The map base has been used in the development of new mapping for the Horsham mapsheet. |
| Major agricultural soils of the Wimmera Irrigation area | High intensity mapping (1:35 000) has been preserved in the final soil-landform map. Soil and landform information is of the highest standard from previous settlement soil surveys (Murtoa, Horsham, Quantong). Soil descriptions for the map units are extremely detailed and informative relating to landscape and formation processes. While overlap occurred with mapping of the soil associations, this mapping took precedence due to scale and detail of mapping. |

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Table 2 continued

| Survey title | Functional role in map creation |
|---|---|
| Soils of the eastern Wimmera | Mapping for the Rupanyup, Donald and Charlton 1:100 000 mapsheets as landforms and soil associations provides the base for the final soil-landform map. Units were refined using radiometrics, especially prior stream complexes and plains. The survey extends to the east beyond the WCMA boundary and has only limited overlap with the *Land inventory of the Wimmera Systems and Rocklands Water Supply Catchment* mapping. The report is quite detailed from a soils perspective with numerous representative profiles included. Landforms defined have been incorporated, however due to the subtlety of the landscape are dubious in certain areas. |
| Land inventory of the Wimmera Systems and Rocklands Water Supply Catchment | This report entails mapping for the upper Wimmera, Grampians Ranges and western Black Range areas as 150 topographic (landform)-soil combinations. Based around the Grampians Ranges storages, the mapping has been produced using aerial photography interpretation procedures and soils information assigned using the Factual Key (Northcote 1979) classification scheme. The survey is quite extensive and provides a very useful mapping base in the upper Wimmera area. There were modifications made to mapping using DEM, geology and radiometrics to improve the precision of boundaries as well as define new units. While soils information was collected as part of the original mapping process, this information has been lost and therefore placed a limitation on the usefulness of the assigned soils data. Overlap with the soil-landform mapping for the *Natimuk* 1:100 000 mapsheet, *A study of land in the Grampians area* and new mapping for the Horsham mapsheet saw numerous inconsistencies with these surveys. |
| A study of land in the Grampians area | The landsystems mapping for the Grampians area provides 18 landsystem descriptions with numerous disaggregations of these landsystems into land units. Soil and landscape information is captured in tables and has been used extensively owing to the useful level of detail recorded in this report. Mapping covers the Grampians Ranges, Horsham south plains and Mount William Creek catchment areas. Overlap with the Wimmera Systems and Rocklands Water Supply Catchment and new mapping for the Horsham 1:100 000 mapsheet occur. |
| A reconnaissance survey of the soils of the Shire of Kowree, Victoria | Undertaken in the 1950s, this reconnaissance survey provides very useful background mapping that overlaps with the West Wimmera shire mapping and mapping of the Goroke/Natimuk 1:100 000 mapsheets. Unit descriptions have often been reserved through all mapping overlaps, however the boundaries and extent of units fluctuates from survey to survey. Soil point information is limited while the mapping provided an extremely useful quality checking base for more recent mapping. |

Continued next page

Table 2 continued

| Survey title | Functional role in map creation |
|---|---|
| Natimuk | Map units represent major landform patterns across the Natimuk 1:100 000 mapsheet. All map units include landform elements, morphology and element type as well as dominent soils and other soils. Descriptions of dominant soils are provided along with a reference site. The mapping has proved extremely useful and is of high quality when viewed against the DEM, geology and radiometrics. Little modification occurred to linework except along mapsheet boundaries where linework was altered to allow for seamless mapping along all tile boundaries. No mapping at the designated scale (1:100 000) existed south of this tile apart from landsystems mapping of the Grampians area and the Kowree reconnaissance mapping. |
| Landscapes and soils of the Goroke area | Map units represent major landform patterns across the Goroke 1:100 000 mapsheet. All map units include landscape (including percentage coverage), landscape position as well as dominent soils. Descriptions of dominant soils (depth, texture and colour) are provided for all units. The mapping proved extremely useful and is of high quality when viewed against the DEM, geology and radiometrics in addition to pre-existing mapping of the Shire of Kowree and Shire of West Wimmera. Linework was integrated with the Shire of West Wimmera mapping to develop a seamless map along all tile boundaries. Mapping at the designated scale (1:100 000) to the south of this tile included soil-landform mapping of Kowree Shire and West Wimmera Shire. |

As a number of surveys have been edited to develop a seamless map coverage of the WCMA region, some of existing units (soil-landform or landsystem) have been preserved. All soil-landform units created were assigned a unique numerical code to represent either an existing map unit, or newly created unit. The extents of the surveys and data gaps in information are presented in Table 2 and Figure 20. The soil-landform units developed as part of the LRA project for the WCMA region are to be used at 1:100 000 scale. Soil-landform units are listed in the Section 2 (Geomorphology) under relevant geomorphic tiers. The soil-landform data has also been used to produce inherent susceptibility to land degradation maps.

In future the availability of soil-landform unit information and soil point site data will allow for more specific and detailed applications. These may be used to provide a clear understanding of the potential to develop land for specific agricultural enterprises and to identify specific limitations inherent within the natural resource base. The ability to access detailed soil point information, as well as soil and land spatial units will benefit many modelling applications currently used to assess land resource management and water quality aspects, for example, Land Use Impact Model (LUIM), Soil and Water Assessment Tool (SWAT) and the Catchment Assessment Tool (CAT).

Detailed soil-landform unit descriptions are accessible via the CD-ROM. Soil profile descriptions are provided in Section 4 (Soils) under relevant soil group headings.

### Datasets used to refine map boundaries, and create units for areas with no previous survey coverage

A number of geospatial datasets were used in a GIS to aid in refining boundaries between overlapping soil and land surveys, and to map new soil-landform units for areas with no existing coverage at an adequate scale. Some of these datasets and their use in these processes are explained.

#### *Geology*

Geology mapping is available for this region at 1:250 000 scale from the DPI Corporate Geospatial Dataset GEOL250 (O'Brien 2001) and was used as a consistent base to assist in boundary refinement, but also in defining likely sources for soils. Improved 1:100 000 scale geology digital map base was released by DPI's Geological Survey of Victoria (GSV) for the Ararat 1:100 000 mapsheet and proved invaluable in associating soils and landforms with the geology of the Western Uplands. Geological information was also used in soil-landform tabular descriptions (refer to tabular descriptions in following section). The nomenclature used conforms to that developed and recently revised by the GSV.

***Radiometrics***

Airborne gamma radio spectrometry (GRS) was useful in the detection of changes in soil properties, but required validation by ground truthing to determine intrinsic soil properties. The use of radiometrics was particularly relevant in differentiating terrain with unconsolidated material, such as the plains country, and complemented the digitial elevation data in the Western Uplands. Radiometrics was also used with geology to identify topographical relationships concerning colluvial and alluvial material.

***Digital elevation models***

Digital elevation models (DEMs) have become widely used in the last 20 years as they enable better visualisation and interrogation of topographic features.

A DEM is generically described as 'a spatially geo-referenced dataset that is a popular way of encoding the topography for environmental modelling purposes'. DEMs are directly compatible with remotely-sensed data sources and can be used to represent complex terrain units, given an adequate resolution.

Generally, DEMs have been derived from topographic data using contour data, spot heights, hydrology and boundaries (shore line, state, 1:100 000 tile) and provide the data to analyse the shape of the surface which affects the soils and hydrological properties of the landscape.

Some general derivatives from DEMs include:

- slope, slope length and slope position
- aspect
- drainage network and catchment boundaries
- hydrological indices and watertable indices
- climate variables
- input to estimation of soil parameters
- input to land component and soil type mapping
- viewshed analysis and visualisation
- visualisation
- environment modelling including salinity, species distribution, spread models etc.

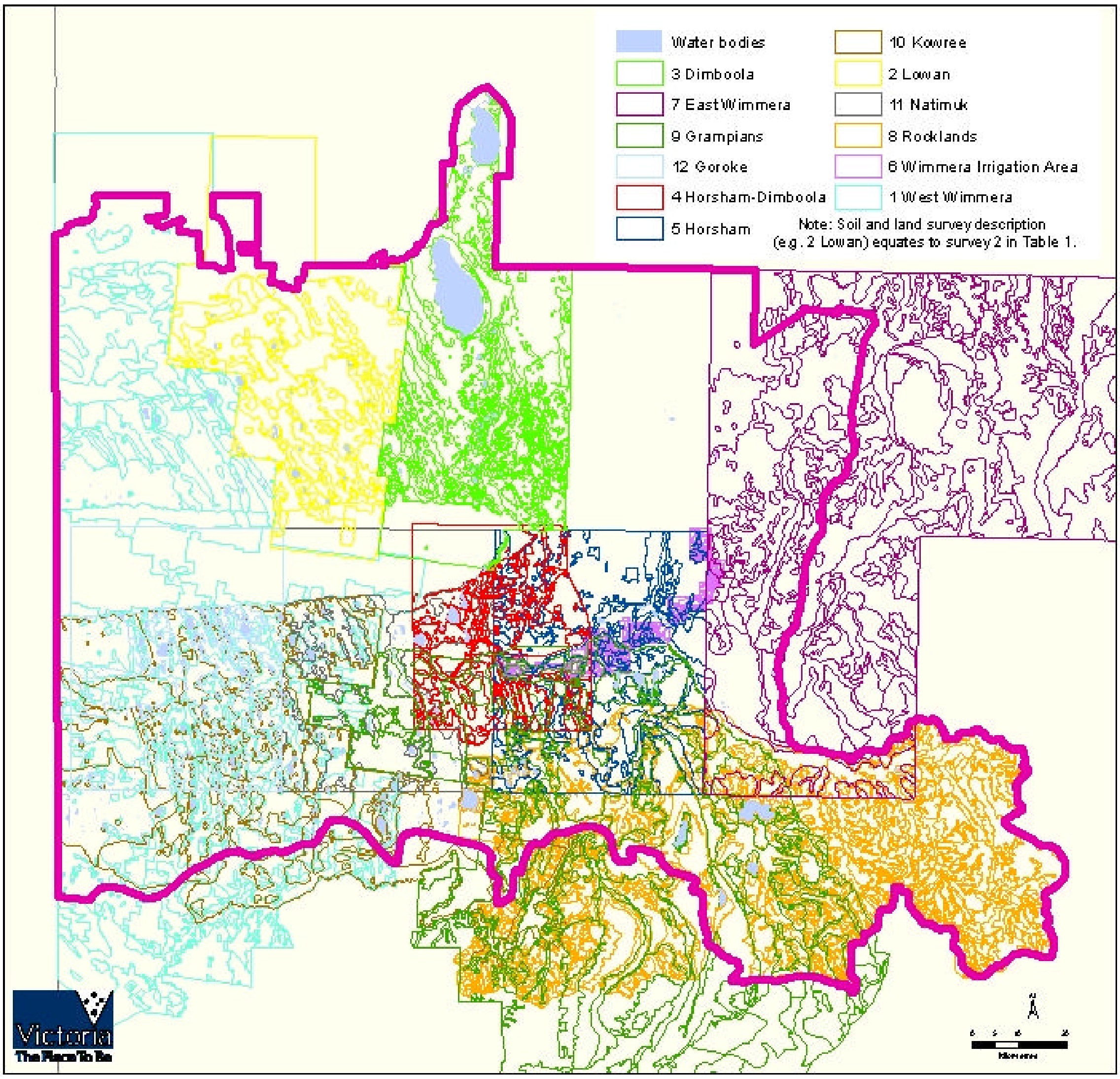
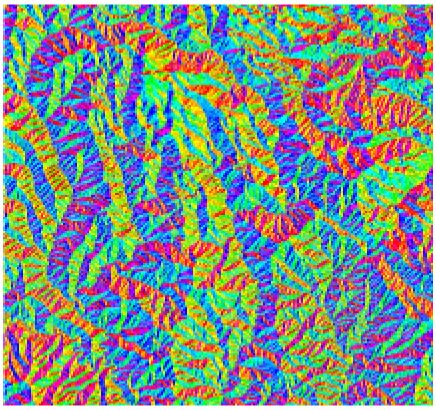



Figure 20 Existing soil and land surveys within the WCMA region used in mapping soil-landforms of the catchment

One of the most useful properties of DEMs is the ability to reclassify datasets. For example, slope, aspect and elevation can be classified to meet requirements or parameters of landscape components (as seen in Figure 21).



Aspect classification

Slope classification

Figure 21  Three dimensional classification of DEM to three different datasets (aspect, slope and elevation)

DEMs have been developed to generate slope ranges and formulate relationships between slope, landform and soil characteristics. DEMs with a 20 m pixel resolution were developed for the WCMA region from 1:25 000 scale topographic data. In the more steeply dissected country the DEMs provided an excellent background dataset to assess for changes in landform and associated soils/soil distribution. The DEMs were also used to generate slope classes and relative elevations that conform to erosional landform patterns as defined in McDonald et al. (1990). These derivatives are useful to identify areas of changing landforms and break-of-slope, indicating the occurrence of a changing process, as well as assisting classification of landforms into a consistent format (e.g. cones classified to hills, low hills and rises).

### *Soil point data*

The collection of soil point site information has been used to define the associations between soils and landforms. Soil point information has also provided a basis for allocation of dominant soil attributes within each soil-landform unit. Nearly 1000 sites exist from soil and land surveys, including those collected during the course of this project. Additional soil site information has been used from various soil site programs across western Victoria. These programs include the National Soil Fertility Program (CSIRO 1968-1972), Top Crop (Imhof unpublished), Horsham historic sites (Newell & Thorn 1967; Forrest 1978), Wimmera core service (Martin 1969). Over 190 soil profile descriptions are provided on the CDROM with 161 of these geographically located on the 1:100 000 soil-landform maps. A review of known existing soil sites for studies and surveys of the WCMA region is documented in Robinson et al. (2003c).

## Units

In this study, the soil-landform unit is the principal mapping unit and has been classified and mapped at 1:100 000 scale across the entire WCMA region. Within the geomorphological framework these soil-landform units occur at or below the geomorphological sub-regional level (Tier 3). The generation of these units incorporated information from historic reports and office-based GIS techniques in association with fieldwork, to ascertain and validate soil descriptions for unique soil-landform units.

These soil-landform units provide the base dataset from which the susceptibility to land degradation themes are derived. This study has identified and provided an inventory of soil-landform units across the area with inherent susceptibility to erosion, waterlogging and soil structure decline.

Soils descriptions, classifications and groupings have been defined using soil point data from existing studies and new fieldwork. Soils are described to national standards and are compared on the basis of their attributes and classification, using *The Australian Soil Classification* (Isbell 1996). Landform (or landform pattern) has also been classified on the basis of relative relief, such as plains, low hills and mountains, and modal slope variations (gently, undulating, rolling, moderately steep, steep, very steep-inclined and precipitous). These comply with national standards as set out in the *Australian Soil & Land Survey Field Handbook* (McDonald et al. 1990). Landforms were further distinguished according to changes in their lithology (geology).

The soil-landforms of the relevant studies used have been delineated by a combination of aerial photo interpretation, correlation and quality control using airborne radiometrics, DEM and field examination. All soil and land survey prior to 2000 used black and white aerial photographs stereoscopically at a scale of approximately 1:80 000 (1:100 000 soil-landform mapping) and 1:25 000 (1:35 000 soil-landform mapping), and reveal geomorphic patterns for the soil-landform mapping of each study. Each area was examined in the field to check the accuracy of the aerial photograph interpretation and to collect data regarding the nature of the soils, the native vegetation, the angle and shape of slopes and the nature of the parent material. Climatic data was also considered in delineation of soil-landform units.

Representative sites or 'type sites' were chosen for each of the most commonly occurring land components in order to examine in detail the nature of the soils, the structure and floristics of the associated native vegetation and their interrelations with other variables.

From the assembly of these studies and additional mapping, over 100 soil-landforms have been defined for the WCMA region. These range in size from less than 250 ha, to in excess of 100 000 ha. Some of the smaller units occurring near the edge of the study area are widespread in adjacent CMA regions.

Data collected on each soil-landform unit is presented in tabular form with accompanying background unit information, photographs, topographic section, three-dimensional representation and location of where the unit occurs within the catchment.

## Tabular descriptions

Components are allotted numbers to aid in identification. Representative parts of each soil-landform unit have been mapped on stereo air photographs at a scale of approximately 1:25 000 to define and measure the areas of the individual components. These areas have been extrapolated to give an estimation of the relative proportions of each component. For soil-landform units near the edge of the study area, these proportions may not be relevant to adjacent areas. This methodology for defining components within units has been adopted for many soil-landform units with soil and land surveys pre 2000 using an almost identical procedure with varying scales of photomosaics/stereo pairs for identification of components (refer to existing studies for comprehensive methodology).

*Climatic data* is derived from climatic geospatial datasets for Victoria. These datasets have been interpolated from existing weather station information provided by the Bureau of Meteorology. Data presented includes: annual rainfall for each soil-landform unit, the wettest month and the driest month.

*Temperature data* are the average annual daily values in February (maximum) and July (minimum) extremes.

The major *seasonal growth limitaton* (precipitation less than evapotranspiration) has also been provided.

*Restrictions to plant growth* (growing season) occur to varying extents due to low temperatures in winter, and lack of available water in summer. These restrictions are of somewhat lower impact today with a range of summer dormant, winter active pasture species available on the market. It should be noted that soil moisture storage extends the growing season beyond the point where potential evapotranspiration exceeds precipitation.

*Local relief* is a measure of the average change in elevation from the top of a hill or ridge to the nearest drainage line within the landsystem. The DEM combined with representative topographic sections enabled an assessment of the relative relief variations across these landscapes. The 1:25 000 stream hydrology network geospatial dataset has been used to determine drainage patterns as well as drainage density.

*Native vegetation* descriptions for soil-landform units have been assigned using Ecological Vegetation Class (EVC) information from the geospatial dataset. Area of disturbance, plantations or waterbodies have not been included in totals of these units.

*Soil profile information* including parent material, description, surface texture, permeability, depth and soil type sites has been included. This information has been derived from previous soils allocated to landforms of existing studies, thus preserving the detail and integrity of this data as well as incorporating new investigations. Soil descriptions derived from existing studies have been updated to reflect changes in soil classification and the adoption of the Australian Soil Classification (Isbell 1996). A key change has been the adoption of the soil colour classes defined within the ASC. Due to the varying age of soil data earlier soil classification/descriptions (Northcote 1979) are given where available. This should provide a link for those who are mainly familiar with the older scheme.

Additionally these soils have all been assigned to *soil groups* (Wimmera Soil Groups) that reflect a combination of geomorphology and soil relationships. There are 41 soil groups. Land component soils have been assigned to a Wimmera Soil Group (WSG). This was developed to encompass the variety of soils in the existing studies (greater than 200) and to simplify presentation of soil information.

*Soil site information* has been included for sites that are either located specifically within that unit and component (denoted in bold text), or are considered sites suitable as representative of the described soil.

A five-class system has been used for the estimation of *permeability* based on profile characteristics such as porosity and texture. The estimate refers to the vertical hydraulic conductivity of the solum, which is limited by the least permeable horizon. Sands with no compacted layers have very high permeabilities while clays, with few pores or cracks, have very low permeabilities. This system has been adopted along with information captured from all the landsystem surveys of the catchment.

*Soil depth* refers to the distance below the surface to solid rock or to a layer that serves as an impediment restricting root penetration and water movement.

The main existing *land uses* have been listed. Active recreation includes the use of vehicles such as trail bikes, dune buggies, four-wheel drive vehicles and other forms of 'adventure sports'. Passive recreation refers to less potentially destructive pursuits such as picnicking, camping and bushwalking.

The forms of *soil deterioration* found to occur in each component, the critical features of the landscape, and the processes leading to these forms of soil deterioration are also outlined.

An example of a tabular description is presented in Table 3 along with a description of where information derived for soil-landform unit descriptions has been sourced.

Table 3 Tabular unit description example with described sources for relevant information

| *Component*<br>*Proportion of landsystem* | Component no. (e.g. 1, 2, 3 etc.)<br>Percentage of overall unit (e.g. 10%) |
|---|---|
| **CLIMATE** | |
| Rainfall (mm) | Annual average rainfall: calculated from the climate geosptial datasets held at CLPR for rainfall (derived from weather stations across Victoria) |
| Temperature (°C) | Minimum (July) and Maximum (January) average |
| Precipitation less than potential evapotranspiration | Geospatial datasets have provided the source for months where precipitation is less than potential evapotranspiration |
| **GEOLOGY** | |
| Age and lithology | Sourced from the 1:250 000 geological mapping held by DPI's Minerals and Petroleum group |
| Geomorphology | Defined in accordance with recent mapping by the Victorian Geomorphological Reference Group |
| **LAND USE** | Land use is a general assessment of major practices within units. This information is derived from surveyor knowledge and observations collected in field survey |
| **TOPOGRAPHY** | |
| Landscape | Source: existing land resource assessment surveys and field assessment |
| Elevation range (m) | Source: 1:25 000 DEM |
| Local relief (m) | Source: 1:25 000 DEM |
| Drainage pattern | 1: 25 000 stream hydrology network |
| Drainage density (km/km$^2$) | 1: 25 000 stream hydrology network |
| Landform | Aerial photograph interpretation and field assessment |
| Landform element | Aerial photograph interpretation and field assessment |
| Slope and range (%) | Aerial photograph interpretation and field assessment |
| Slope shape | Aerial photograph interpretation and field assessment |
| **NATIVE VEGETATION** | |
| Ecological Vegetation Class (EVC) | Derived from the EVC geospatial dataset |
| **SOIL** | |
| Parent material | Sourced from the 1:250 000 geological mapping held by DPI's Minerals and Petroleum group and field survey descriptions |
| Description (Wimmera soil group) | Local soil description (provided via existing soils information or from analysis of soil sites) |
| Soil type sites | Soil type sites have been captured allowing the user to refer to sites that are either located specifically within that unit and component (denoted in bold text), or are considered sites suitable as representative of the described soil. |
| Surface texture | Representative soil site textural information |
| Permeability | Representative soil site textural information |
| Depth (m) | Representative soil site textural information |
| **LAND CHARACTERISTICS, POTENTIAL AND LIMITATIONS** | The land characteristics are a base interpretation by the soil surveyor of the important critical land features, processes and forms. This is derived from soil-landform properties and land features that increase likelihood of erosion and degradation. |

## Soil-landform unit descriptions

Soil-landform units have been developed using processes outlined previously. There are 106 discrete soil-landform units mapped for the WCMA region excluding the Horsham township and lakes (terminal lakes and Grampians storages). A soil-landform unit is based primarily on land pattern while the land component, or element is a subset of these (refer to *Australian Soil & Land Survey Field Handbook*, McDonald et al. 1990). Although historical surveys and existing land resource information were used as a guide in the development of these soil-landform units, nearly 150 additional soil sites were collected as part of this project. These additional sites contributed to the detailed soil profile information, and when related to the local landform features provide the basis of the soil-landform unit.

The soil-landform units defined for this study are listed under geomorphological units in Section 2 (Geomorphology) numerically with a brief unit description, as well as the area and proportion of land each unit consists of. Soil-landform units can be accessed from the 'soil-landform' drop-down list on this CD-ROM and accessed on the CD-ROM by following links from the soil-landform map base.

Within the soil-landform unit descriptions the landform features and characteristics are defined and described. The land component descriptions provide a major soil type, relating this to soil groupings identified for the Wimmera region.

Map products generated from the soil-landform units for the project include:

- Soil-landform unit base map
- Soil-landform unit base map with sites provided on the CD-ROM
- Land degradation susceptibility maps covering:
    - gully and tunnel erosion
    - sheet and rill erosion
    - wind erosion
    - soil structure decline (compaction)
    - soil pH (topsoil and subsoil)
    - soil sodicity (topsoil and subsoil).

These maps can be found on the CD-ROM accompanying this report and can be accessed by following the links from the CD-ROM index to the map section.

# 4 Soils

Soils are variable in space and this reflects the influence of environmental factors such as climate (past and present), parent material (lithology), position in landscape (topography) and time. Vegetation types are also a part of this process and form an integral relationship with soil development, accumulation of organic matter and recycling of nutrients.

As a consequence of variable climate (mainly rainfall), parent material and topography, there is a large range of soils in this region. This range of environments is reflected in the geomorphology of the region, providing the framework for the range of soil types.

Given the large number of soils identified by previous studies and surveys (Table 1) in different parts of the WCMA (e.g. Sibley 1967; Badawy 1981a,b; Badawy 1984) a scheme of 41 soil groups (Wimmera Soil Groups) has been adopted to simplify presentation in this report. Groups largely reflect the classifications made in the earlier surveys and, as classifications change and understanding evolves, revision of these groups will undoubtedly be made in future.

Sites representing soils in these groups are accessable via the ‘soil site’ drop-down list. Accompanying the written soil descriptions are chemical data. Methodologies relating to this chemical data can be accessed via the appendix drop-down list for the Otway soil descriptions, and for all remaining descriptions. Surveyors and studies of sites presented in this report are listed in Table 1.

## 4.1 Wimmera Soil Groups

The description of the Wimmera Soil Groups (WSG) is based on the texture profile of the soil, predominantly the amount and distribution of clay with depth. This is an indication of soil development and the age of the soil. This approach has been the basis for describing Australian soils for the last 30 to 40 years through the Factual Key (**FK**: Northcote 1971) and the Australian Soil Classification (**ASC**: Isbell 1996). Linked to this is the distribution of nutrients which has a major influence on soil behaviour and performance. The sodicity of the soil is seen as a major (unfavourable) determinant of soil behaviour by influencing soil physical properties through increased dispersion of soil aggregates.

Soil texture groups include those with little change with depth such as sands (coarse), loams (medium) and clays (fine); those such as earths with a gradational change (increasing clay) with depth. Soils with a clear change from a light textured (sandy or loamy) surface over a heavy (clay) subsoil are referred to as having texture contrast profiles (minimum difference of 20% clay between surface and subsoil). ‘Texture contrast’ is the current terminology (Isbell 1996) that replaced the term ‘duplex’ used in the Factual Key (Northcote 1971).

Broad soil groups are:

- (i) Sodic texture contrast soils
- (ii) Non-sodic texture contrast soils
- (iii) Gradational (earths) or uniform soils
- (iv) Sands
- (v) Clays
- (vi) Seasonally wet soils

The 41 Wimmera Soil Groups were derived by further dividing these broad soil groups using the geomorphological divisions (Section 2) and other soil characteristics, as outlined below:

- Sodic texture contrast soils: subdivided on colour. Sodic is defined as the upper subsoil having an ESP greater than 6.
- Non-sodic texture contrast soils: subdivided on colour. Non-sodic is defined as the upper subsoil having an ESP of less than 6.
- Gradational (earths) or uniform soils: subdivided on colour or calcareous nature. Many of the gradational soils have heavy (clayey) subsoils.
- Sands: subdivided on the basis of depth and the presence or absence of pans such as 'coffee rock'.
- Clays: subdivided according to colour and whether cracking and/or self-mulching.
- Seasonally wet soils

Other soil properties such as mottling, structure, total depth of soil, and depth of surface and subsurface (horizons) soils are outlined in the soil group descriptions.

A number of soil site examples (usually three key sites) are given for each Wimmera Soil Group which aims to give an indication of the major soils, with other sites mentioned if they occur (see also unit descriptions). A distribution figure is presented for all soil groups (dark moroon text indicating dominance in these areas).

Within the Wimmera Soil Groups (WSGs) there are a range of soils, and some outliers in terms of classification. Where the area of a broad lithology and number of soil sites is limited a larger range of soils may be tolerated to minimise the number of soil groups. For example, sodic and non-sodic soils may be in the same WSG as are gradational and uniform soils of Cainozoic landscapes.

***Trends***

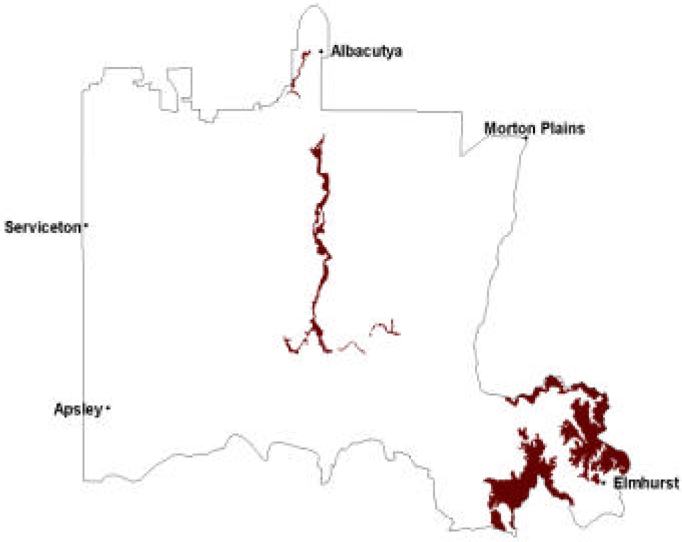
Some broad trends include the association of particular soils or soil properties in conjunction with the broad parent materials. For example, the texture contrast soils on the Cainozoic landscapes have lighter surface soils than texture contrast soils on the basic volcanics (basalt). There is a significant silt component to soils associated with the Palaeozoic sediments in the Western Uplands which contributes to their dispersibility and higher susceptibility to water erosion. Another trend is the increasing sodicity of texture contrast soils on sedimentary terrain from south to north as rainfall (and leaching) decreases. There are often very sharp changes in soil type on the clay plains (gilgai) and the sedimentary plains (sands to texture contrast).

More specific inferences require more detailed work, which would complement these broad soil groupings.

Table 4 Study titles and survey codes for soil site prefix (e.g. WLRA)

| Soil survey or study prefix | Surveyor/s, year of publication and report title | Total number of sites | Number of sites included in this report |
|---|---|---|---|
| ALRA | Robinson N, Rees D, Boyle G, Bluml M, Reynard, K, Youman K, Sheffield K (2004) Ararat Rural City land capability pilot project. Department of Primary Industries. | 87 | 8 |
| DOAAR | Badawy N, Lewis N (1982) Soils of the vineyards of the Ararat district. Department of Agriculture. | 19 | 0 |
| DOAGW | Badawy N, Lewis N (1982) Soils of the vineyards of the Great Western district. Department of Agriculture. | 76 | 5 |
| DOAHG | Badawy N, Lewis N (1982) Soils of the vineyards of the Halls Gap district. Department of Agriculture. | 11 | 4 |
| GL | Baxter N, Robinson N, Rees D, Boyle G, Imhof M (2001) A land resource assessment of the Glenelg-Hopkins region. Department of Natural Resources and Environment Victoria. | 175 | 1 |
| GRAMP | Sibley GT (1967) A study of the land in the Grampians area. Soil Conservation Authority. | >20 | 20 |
| GW | Bluml M, Boyle G (1999) Feasability study for vineyard development Great Western area - a land suitability analysis. Department of Natural Resources and Environment Victoria. | 31 | 3 |
| HOR | Martin J, Imhof M (1992) North West Reconnaissance Survey (unpublished). Department of Agriculture and Rural Affairs. | >400 | 3 |
| LP | Imhof M et al. (unpublished) Navarre and Districts Landcare Group - soil pits. Department of Primary Industries. | 4 | 4 |
| LS | Imhof M, Thompson S, Rees D (1997) Lowan land inventory and assessment. Department of Natural Resources and Environment | 27 | 27 |
| NA | Maher J, Martin J (1990) Natimuk. Department of Agriculture and Rural Affairs (unpublished). | 81 | 4 |
| TopCrop | Imhof M (unpublished) TopCrop state focus site - soil pits. Department of Natural Resources and Environment. | 6 | 6 |
| WIA | Martin J, Imhof M, Thompson S (1996) Major agricultural soils of the Wimmera Irrigation Area. Department of Natural Resources and Environment. | >36 pits<br>>100 auger | 36 |
| WIM | Brown A (unpublished) Department of Primary Industries | 5 | 5 |
| WLRA | Robinson N, Rees D, Reynard K, Imhof M, Boyle G, Youman K, MacEwan R (2005) A land resource assessment of the Wimmera region. Department of Primary Industries. | 148 | 34 |
| WW | Baxter N, Imhof M, Brown A, Rees D (1996) Agricultural and horticultural land suitability for the West Wimmera Shire. Volumes 1 & 2. Department of Natural Resources and Environment. | 31 | 31 |

## 1. Red texture contrast soils/Dissected Uplands: Palaeozoic non-granitic plateaux, mountains, hills and plains




This soil has developed on mainly sedimentary and metamorphic material (rock or colluvial material) and occasionally on acid volcanics in the Western Uplands. This soil is slightly acidic, often tending to neutral with depth.

The surface soil is usually a dark weakly structured sandy loam to sandy clay loam. It overlies a reddish brown weakly structured sandy clay loam to fine sandy clay loam subsurface horizon that is also weakly structured and contains variable amounts of coarse sandstone fragments. This horizon may be bleached. There is a clear change to a yellowish red medium clay upper subsoil horizon. This is strongly structured (with medium to fine sized peds) and contains weathered sandstone fragments. At depth the profile grades into lighter textured material and the underlying bedrock (Palaeozoic sandstone). The depth is about 60 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 15 cm for the subsurface.

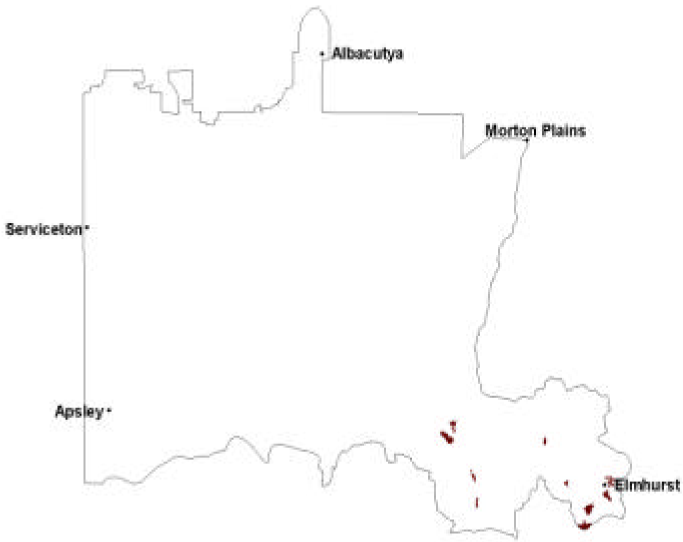
Notable features include:

- Texture contrast and associated structure differences between the surface horizons and subsoil.
- Variants may be browner or paler in poorer drainage situations and possibly more dispersive.
- The deeper subsoil may become sodic, calcareous and contains manganese segregations.
- The lighter textured topsoil may be susceptible to sheet, rill and wind erosion.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| LP83 | Landsborough footslopes | Hillcrest | Haplic, Mesotrophic, Red Chromosol | Dr2.21 | T7254 – ST ARNAUD |
| DOAGW32 | Rhymney hills | Hillslope | ?-Sodic, Mesotrophic, Red Chromosol | Dr2.12 | T7423 - ARARAT |
| LP82 | Pyrenees Ranges | Hillslope | Bleached-Sodic, Mesotrophic, Brown Chromosol | Dy2.42 | T7254 – ST ARNAUD |

## 2. Sodic red texture contrast soils/Dissected Uplands: Palaeozoic non-granitic plateaux, mountains, hills and plains




This soil has developed on sedimentary and metamorphic material (rock or colluvial material) in the Western Uplands. This soil is slightly acidic, often tending to neutral or alkaline with depth.

The surface soil is often a dark moderately structured sandy loam to sandy clay loam. It overlies a brown loamy/clayey sand subsurface horizon that is massive, sporadically bleached and contains variable amounts of coarse sandstone fragments. There is a clear change to a yellowish red, medium to medium heavy clay subsoil horizon, which is mottled (light olive brown). This is strongly structured (with medium to fine sized peds), with weathered sandstone fragments. At depth this grades into lighter textured weathered material and the underlying bedrock (Palaeozoic metasediments). The depth is about 70 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 10 cm for the subsurface (up to 25 cm or more). Lower slopes have deeper profiles. Includes red-mottled brown and yellow variants.

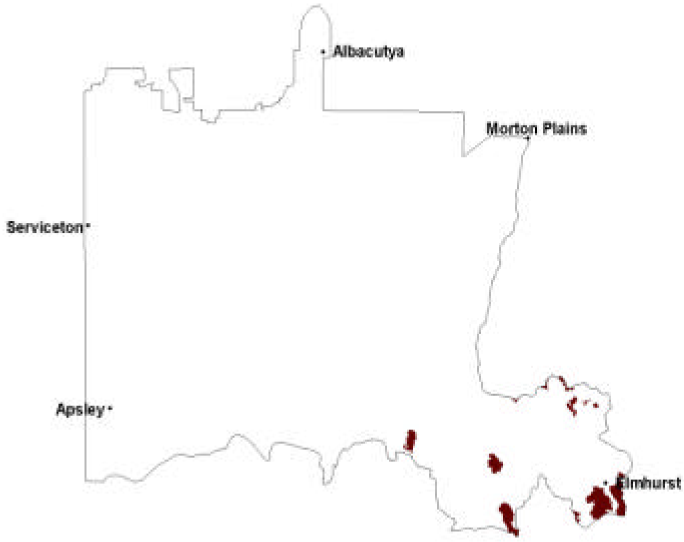
Notable features include:

- Texture contrast and associated structure differences between the surface horizons and subsoil.
- Variants may be browner or paler in poorer drainage situations and possibly more dispersive.
- The deeper subsoil is strongly sodic and highly dispersive.
- The lighter textured topsoil may be susceptible to sheet, rill and wind erosion.
- Some susceptibility to upper subsoil compaction.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| ALRA81 | Mount Dryden | Middle slope | Eutrophic, Mottled-Subnatric, Red Sodosol | Dr3.32 | T7423 - ARARAT |
| DOAGW22 | Rhymney hills | Middle slope | Mesotrophic, Mottled-Subnatric, Red Sodosol | Dr3.32 | T7423 - ARARAT |
| WLRA141 | Pyrenees Ranges | Lower slope | Eutrophic, Mottled-Subnatric, Brown Sodosol | Db2.43 | T7523 - BEAUFORT |
| WLRA143 | Pyrenees Ranges | Lower slope | Eutrophic, Mottled-Hypernatric, Brown Sodosol | Dy3.42 | T7523 - BEAUFORT |

## 3. Yellow texture contrast soils/Dissected Uplands: Palaeozoic granitic plateaux, mountains, hills and plains




This soil has developed on mainly granitic (rock or colluvial material) in the Western Uplands. The soil is strongly acidic at the surface, becoming slightly acidic or neutral with depth.

The surface soil is usually a dark brown clayey sand to silty loam with sand and is weakly structured. It overlies a conspicuously bleached clayey sand/silty loam, sandy to sandy light clay subsurface horizon. It is massive (no structure) and contains variable amounts of coarse quartz fragments. There is a clear change to a dark yellowish brown (occasionally very pale brown) strongly medium to finely structured medium clay. Generally it has pale, orange and red mottles and contains some quartz or rock fragments and grades into lighter textured weathered material. The depth is about 120 cm or more with variable depths of the surface horizons, generally 10-20 cm for the surface and 10-40 cm for the subsurface (often deeper). Topographic position is important for depth and profile development.

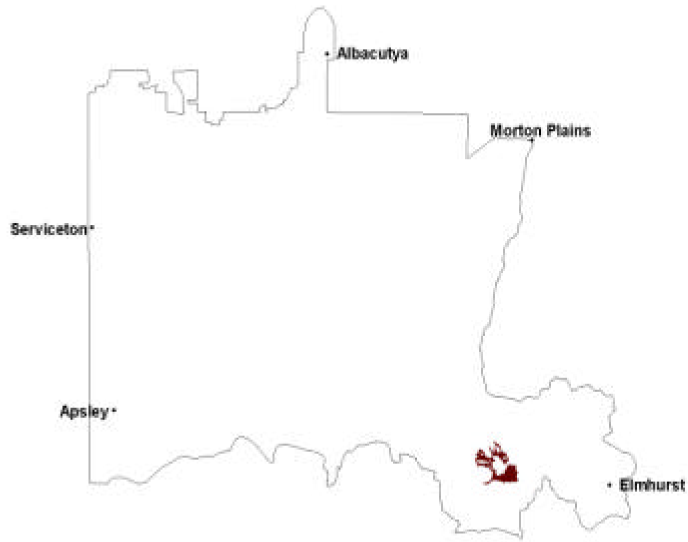
Notable features include:

- Texture contrast between surface horizons and the stronger and coarser structured subsoil.
- Deeper subsoil can occasionally be sodic.
- The subsoil generally has a low to moderate nutrient status.
- These features make these soils vulnerable to erosion, particularly on sloping terrain given poor drainage characteristics and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| GW31 | Sugarloaf granitic hills | Rise | Bleached-Sodic,?, Yellow Chromosol | Dy5.42 | T7423 - ARARAT |
| WLRA91 | Rocky Point low hills and rises | Crest | Bleached-Sodic, ?, Brown Chromosol | Dy3.41/ Dy5.41 | T7423 - ARARAT |

## 4. Sodic, yellow texture contrast soils/Dissected Uplands:.Palaeozoic granitic plateaux, mountains, hills and plains




This soil has developed on mainly granitic (rock or colluvial material) in the Western Uplands. The soil is strongly acidic at the surface, becoming slightly acidic or neutral with depth.

The surface soil is usually a dark brown coarse clayey sand which is massive to weakly structured. It overlies a conspicuously bleached clayey sand subsurface horizon which is massive (not structured). There is a clear change to a very pale brown (occasionally reddish yellow), often with orange and red mottles medium clay upper subsoil. This is strongly structured (with medium to fine sized peds) and grades into lighter weathered material. The profile depth is generally greater than 80 cm or more with variable depths of the surface horizons, generally 5-15 cm for the surface and 20-30 cm for the subsurface (often deeper). Topographic position is important for depth and profile development variations.

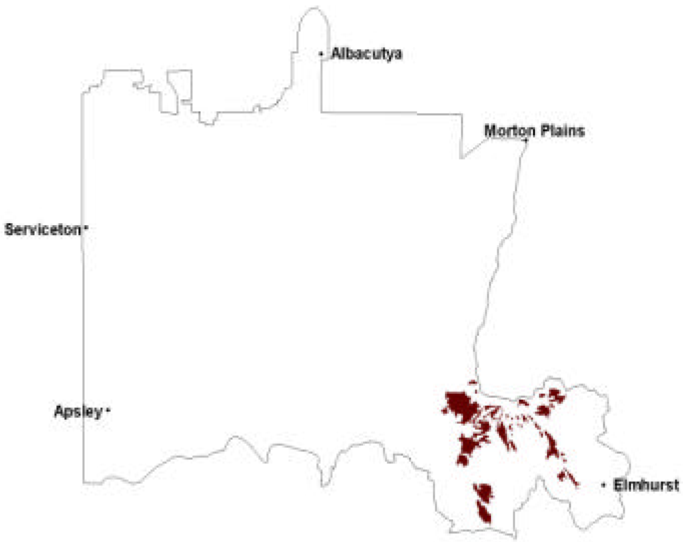
Notable features include:

- Strong texture contrast and associated structure differences between the surface horizons and subsoil.
- Possible strongly sodic lower subsoil.
- The sandy surface horizons have a low nutrient status, low water holding capacity and are highly permeable. The clayey subsoil will restrict water movement and waterlogging may occur in the surface soil as a result after heavy rains.
- These features make these soils vulnerable to erosion, particularly on sloping terrain given poor drainage characteristics and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| GW28 | Sugarloaf granitic hills | Rise | Eutrophic, Mottled-Subnatric, Yellow Sodosol | Dy.5.41 | T7423 - ARARAT |
| GW30 | Sugarloaf granitic hills | Hillslope | Eutrophic, Mottled-Subnatric, Yellow Sodosol | Dy.5.42 | T7423 - ARARAT |

## 5. Sodic and non-sodic, yellow and brown texture contrast soils/Dissected Uplands: Low plateaux on Cainozoic sediments




This soil has developed on mainly Cainozoic (generally gravels and associated unconsolidated material) in the Western Uplands. There are associated minor gradational soils (Kandosols). The soil is slightly acidic at the surface becoming neutral to alkaline with depth.

The surface soil is usually a brown sandy loam, silty to sandy clay loam, with no structure (massive). It overlies a conspicuously bleached loamy sand to sandy clay loam subsurface horizon with no structure (massive) and contains variable amounts of coarse quartz fragments.

There is a clear change to a mottled (pale, yellow and red) yellowish brown to brownish yellow, light to medium clay. This is moderately structured (with coarse to medium sized peds) and grades into lighter textured weathered material. The profile depth is about 140 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 15-40 cm for the subsurface horizon.

Notable features include:

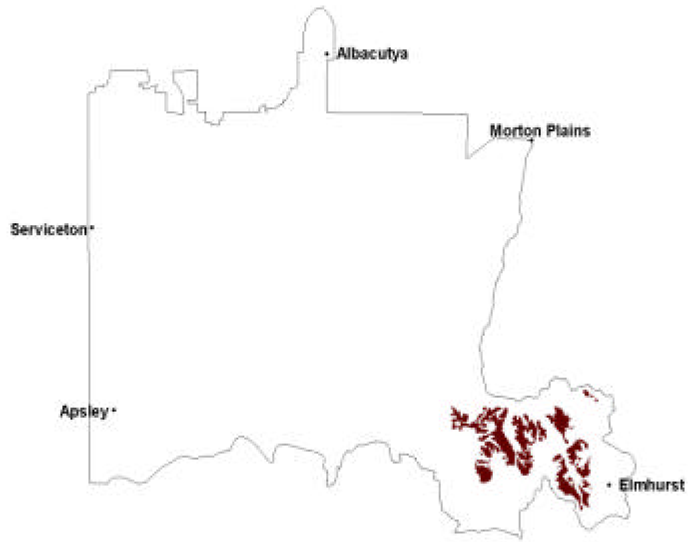
- Texture contrast and associated structure differences between the surface horizons and subsoil.
- The occasionally strongly sodic subsoil.
- Coarse fraction component of the soil and subsurface horizon with low nutrient capacity and low water holding capacity and the densipan above the subsoil.
- These features make these soils vulnerable to sheet and rill erosion particularly on sloping terrain given poor drainage characteristics and lighter surface materials and compaction of the subsurface and upper subsoil horizons.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| DOAGW15 | Great Western rises | Hillslope | Bleached-Mottled, Mesotrophic, Yellow Chromosol | Dy.3.42 | T7423 - ARARAT |

## 6. Sodic and non-sodic, brown and red texture contrast soils/Dissected Uplands: Low Plateaux on Cainozoic sediments

This soil has developed on mainly Cainozoic (generally gravels and associated unconsolidated material) in the Western Uplands. There are associated minor gradational soils (Kandosols). The soils are slightly acidic at the surface becoming neutral to alkaline with depth. Subsoils have strong red mottling.




The surface soil is often a brown sandy loam (silty) to sandy clay loam, which is not structured (massive). It overlies a conspicuously bleached loamy sand to sandy clay loam subsurface horizon which is also massive with few coarse quartz fragments and common ferruginous nodules (buckshot).

There is a clear change to a mottled (red, yellow and brown) brown to yellowish brown, light to medium clay upper subsoil horizon. This is moderately structured (with coarse to medium sized peds) and grades into lighter textured weathered material. The profile depth is about 140 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 15-40cm for the subsurface horizon.

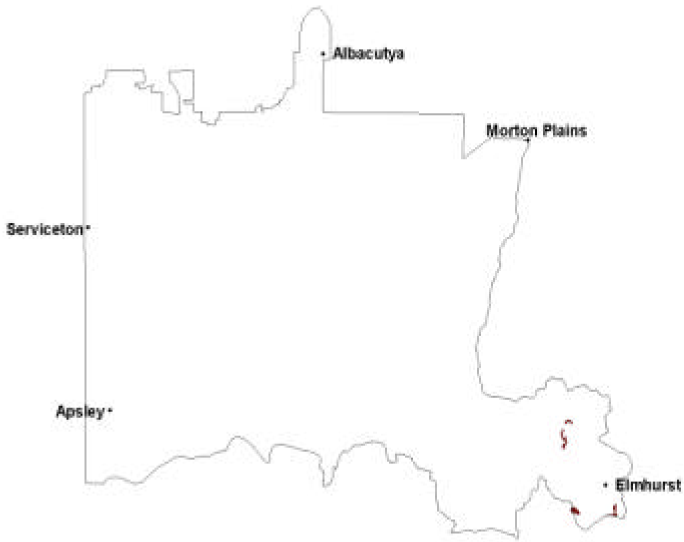
Notable features include:

- Texture contrast and associated structure differences between the surface horizons and subsoil.
- The occasionally strongly sodic subsoil, highly dispersive.
- Coarse fraction component of the upper soil with low nutrient capacity and low water holding capacity and the densipan above the subsoil.
- These features make these soils vulnerable to sheet, rill erosion particularly on sloping terrain given poor drainage characteristics and lighter surface materials and compaction, of the subsurface and upper subsoil horizons.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA141 | Great Western rises | Footslope | Eutrophic, Motttled-Subnatric, Brown Sodosol | Db2.42 | T7523 - BEAUFORT |
| WLRA142 | Great Western rises | Footslope | Eutrophic, Motttled-Hypernatric, Brown Sodosol | Dy3.43 | T7523 - BEAUFORT |
| WLRA143 | Great Western rises | Hillslope | ?, Mesotrophic, Yellow Sodosol | Dy.3.42 | T7523 - BEAUFORT |

## 7. Red gradational or uniform soils/Dissected Uplands: Low Plateaux on Cainozoic sediments




This soil has developed on mainly Cainozoic (generally gravels and associated unconsolidated material) in the Western Uplands. A minor soil type often on upper slopes, sitting on cemented gravel deposits. This soil is acidic, becoming increasingly acidic with depth.

The surface soil is usually a dark to strong brown sandy loam with no structure (massive) and contains variable amounts of coarse quartz fragments. There is a gradual change to a yellowish red sandy clay loam which is weakly structured (medium to fine sized peds), contains abundant fine and medium quartz gravels and grades into lighter textured weathered gravel material. The depth is about 90 cm or more with variable depths of the surface horizons, generally 30-50 cm for the surface.

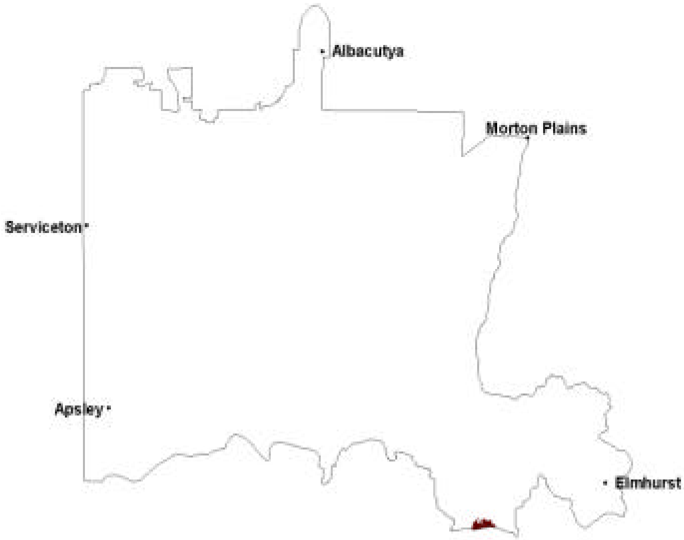
Notable features include:

- Gradual texture change with depth.
- High gravel and coarse fraction component of the soil with low nutrient capacity and low water holding capacity, though well drained.
- Reduced nutrient holding capacity with increasing acidity.
- These features make these soils vulnerable to erosion, particularly on sloping terrain with lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA138 | Great Western rises | Hillslope | Acidic, Eutrophic, Red Kandosol | Gn2.11 | T7523 - BEAUFORT |

## 8. Cracking clay soils/Dissected Uplands: Eruption points and volcanic plains




This soil has developed mainly on Quaternary basic (basaltic) volcanics in the Western Uplands. Some areas have had varying amounts of sand covering the basaltic material. These soils often have slightly acidic to neutral surface horizons becoming neutral to alkaline with depth.

The surface soil is usually a dark brown (occasionally self-mulching) clay loam to heavy clay with moderate structure (with fine to medium sized peds). It occasionally overlies a bleached subsurface horizon (local gilgai feature) with common ferruginised nodules. There is a clear change to a brown to yellow brown, heavy clay upper subsoil horizon. This is strongly structured (coarse sized peds), parting to weakly structured (medium sized peds) with ferruginised nodules in the upper and mid subsoil, becoming more mottled (light grey and yellowish red) in colour and with slickensides with depth, and grades into weathered parent material (basalt). The profile depth is about 120 cm or more with variable depths of the surface horizons, generally 1-10 cm for the surface and 10 cm for the subsurface, occasionally deeper.

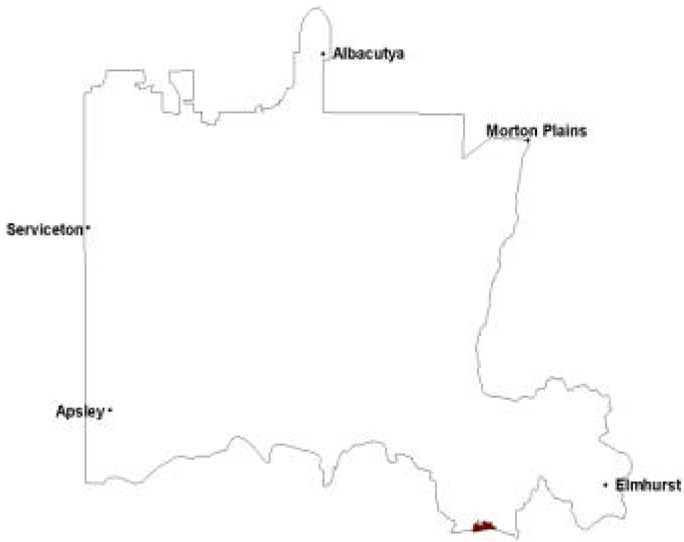
Notable features include:

- Cracking clay soil.
- Variable surface friability (occasional apedal surface, generally pedal).
- Very strong consistence (strength) when dry, particularly the subsoil.
- Ferruginised nodules (buckshot) in the upper soil and occasional calcium carbonate at depth.
- Yellow hued subsoil has restricted soil drainage, generally sodic at depth.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| GRAMP269 | Barton lava plains | Plain | Endohypersodic, Epipedal, Brown Vertosol | Ug5.33/ Ug5.35 | T7423 - ARARAT |

## 9. Sodic brown, yellow and grey texture contrast soils/Dissected Uplands: Eruption points and volcanic plains




This soil has developed on mainly Quaternary basic volcanics (basaltic) in the Western Uplands. Some areas have had varying amounts of sand covering the basaltic material. These soils often have acidic surface horizons becoming alkaline with depth.

The surface soil is usually a dark greyish brown, clay loam with strong structure (with fine sized peds) with weak consistence (strength). This grades into a greyish brown, conspicuously bleached clay loam upper subsurface horizon which has no structure (massive). There is an abrupt wavy change to a mottled greyish brown, clay loam lower subsurface horizon. This is weakly structured and sporadically bleached, often with many ferromanganiferous concretions. There is a clear wavy boundary to red mottled light olive brown, medium to heavy clay. This has weak to moderate structure (with coarse to medium sized peds) generally vertic (slickensides with depth). This grades into weathered basaltic regolith. The profile depth is about 120 cm or more with variable depths of the surface horizons, generally 15 cm for the surface and 20 cm for the subsurface, often deeper (0–40 cm).

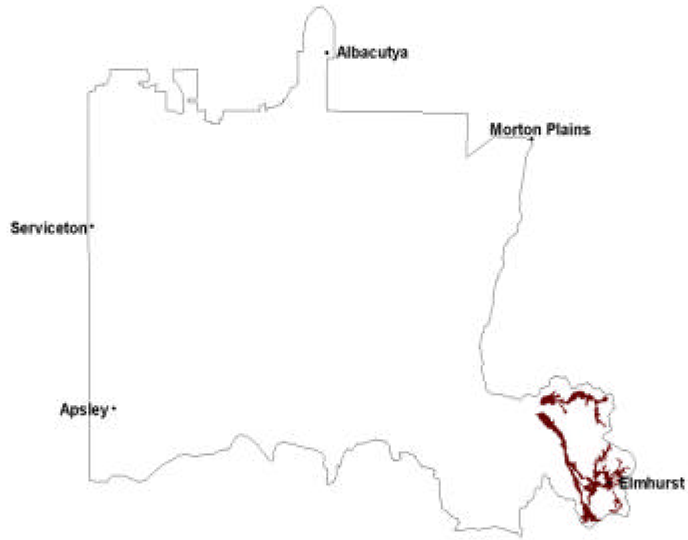
Notable features include:

- Texture contrast (sharp or clear change in clay percentage with depth).
- Vertic properties (including variable topsoil depth and slickensides).
- Strongly sodic subsoil and associated dispersive characteristics.
- Lower nutrient capacity and low water holding capacity of the more acidic, lighter upper soil.
- Limited internal drainage, once moist.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| ALRA69 | Barton lava plains | Plain | Vertic (Ferric), Mottled-Hypernatric, Brown Sodosol | Dy3.42 | T7423 - ARARAT |

## 10. Red texture contrast soils/Dissected Uplands: Terraces and floodplains




This soil has developed on mainly Quaternary alluvial and colluvial unconsolidated material in the Western Uplands. This soil is often strongly acidic at the surface, tending to neutral at depth.

The surface soil is usually a brown sandy loam to sandy clay loam, with no structure (massive). It overlies a conspicuously bleached loamy sand to sandy clay loam subsurface horizon which is also massive. There is a clear change to a yellowish red medium to heavy clay. This has strong structure (with coarse parting to medium sized peds). There is often a brown, pale and red mottle at depth. This grades into lighter textured weathered unconsolidated material. The profile depth is about 100 cm or more with variable depths of the surface horizons, generally 15 cm for the surface and 10-40 cm for the subsurface horizon, occasionally deeper. There is a sandy lighter variant with sandy light clay subsoil with weak structure.

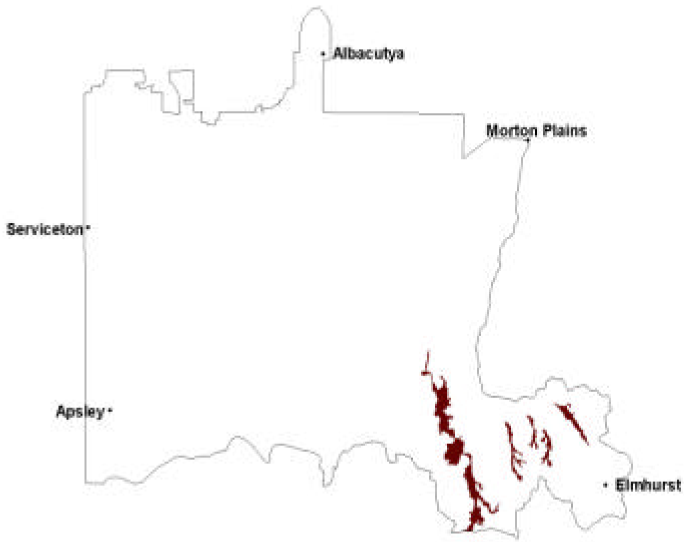
Notable features include:

- Texture contrast and associated structure differences between the surface horizons and subsoil (some restrictive drainage).
- The subsurface horizon sometimes not bleached.
- The lower subsoil may be sodic.
- The coarse fraction component of the upper soil has low nutrient capacity and low water holding capacity, particularly if low in organic matter and leached.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| DOAGW17 | Six-Seven Mile creeks | Plain | Bleached-Mottled, Mesotrophic, Red Chromosol | Dr2.62 | T7423 - ARARAT |
| DOAGW2 | Six-Seven Mile creeks | Plain | Bleached, Mesotrophic, Red Chromosol | Dr2.42 | T7423 - ARARAT |
| LP80 | Wattle Creek covered plain | Terrace | Bleached, Eutrophic, Red Chromosol | Dr2.22 | T7254 – ST ARNAUD |

## 11. Yellow and brown gradational and texture contrast soils/Dissected Uplands: Terraces and floodplains




This soil has developed on mainly Quaternary alluvial and colluvial unconsolidated material in the Western Uplands.

The surface soil is usually a brown loamy sand, which is massive to weakly structured. It overlies a light yellowish brown conspicuously bleached loamy sand to sandy loam subsurface horizon which has no structure (massive).

There is a gradual change to a (brown) mottled light yellowish brown (occasionally yellowish red) heavy sandy loam which is massive. This grades into a silty light clay, which is strongly structured and grades into lighter textured weathered unconsolidated parent material (alluvium). The depth is about 130 cm or more with variable depths of the surface horizons, generally 5-10 cm for the surface and 20-50cm for the subsurface, occasionally deeper.

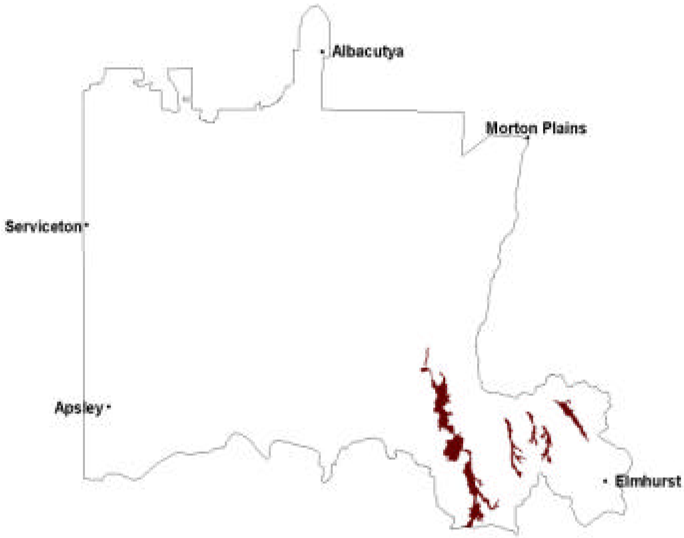
Notable features include:

- Gradational or texture contrast change in clay percentage with depth.
- Variable depth of lighter upper soil with low nutrient capacity variable rooting depth and low water holding capacity.
- Weakly developed structure.
- These features make these soils vulnerable to sheet and rill erosion, particularly on sloping terrain given the lighter surface soils with variable organic matter content.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA66 | Mount Cole Creek | Terrace | Bleached-Sodic, Yellow Kandosol | Gn2.96 | T7523 - BEAUFORT |
| WLRA63 | Mount Cole Creek | Plain | Bleached-Sodic, Red Kandosol | Dr2.42/ Gn3.19 | T7423 - ARARAT |

## 12. Sodic brown, yellow and grey texture contrast soils/Dissected Uplands: Terraces and floodplains




This soil has developed on mainly Quaternary alluvial and colluvial unconsolidated material in the Western Uplands. These soils often have acidic surface horizons becoming alkaline with depth

The surface soil is usually a dark greyish brown, sandy loam to sandy clay loam, which is weakly structured. It generally overlies a yellowish brown silty loam to sandy clay loam subsurface horizon, which is massive and conspicuously bleached. There is a clear change to a mottled (red) yellowish brown, medium to heavy clay, which is often vertic. This soil has weak to moderate structure (medium parting to fine sized peds). Occasionally, calcium carbonate occurs in the mid to lower subsoil. The subsoil grades into lighter textured weathered material (alluvium). The profile depth is about 130 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 25 cm for the subsurface, often deeper (0–40 cm).

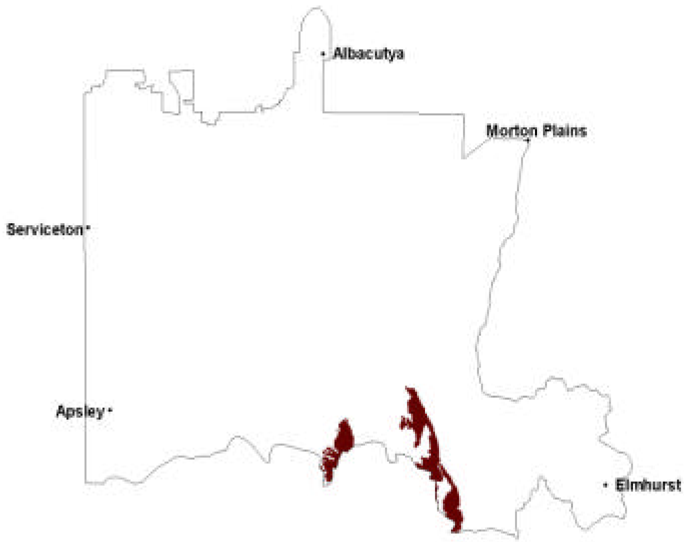
Notable features include:

- Sharp or clear change in clay percentage with depth.
- Vertic properties (including variable topsoil depth).
- Strongly sodic subsoil and associated dispersive characteristics.
- Low nutrient capacity and low water holding capacity of the more acidic, lighter upper soil.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| DOAGW12 | Six-Seven Mile creeks | Plain | Eutrophic, Motled-Subnatric, Brown Sodosol | Dy3.33 | T7423 - ARARAT |
| WLRA144 | Six-Seven Mile creeks | Plain | Eutrophic, Hypernatric, Brown Sodosol | Dy3.42 | T7523 - BEAUFORT |
| WLRA145 | Mount Cole Creek | Plain | Eutrophic, Mesornatric, Brown Sodosol | Dy3.43 | T7423 - ARARAT |
| WLRA148 | Mount Cole Creek | Plain | Vertic, Mottled-Subnatric, Grey Sodosol | Dy3.43 | T7423 - ARARAT |

## 13. Shallow and sandy weakly developed soils/Strike ridges and valleys: Cuesta landscapes




This soil has developed on mainly Palaeozoic sandstone and colluvial material in the Western Uplands, primarily on the Grampian Ranges.

The surface soil is usually a grey or brown loamy sand which is weakly structured. It overlies a conspicuously bleached loamy sand to sandy loam subsurface horizon. This is massive to weakly structured and contains many coarse grained quartz sand. There may be a gradual to clear change to a yellow brown silty or clay loam. This is moderately structured (with medium sized peds), often with some quartz or rock fragments or grading directly into lighter textured subsoil which is apedal (sandy) and then weathered parent material (sandstone). The profile depth is about 70 cm or more with variable depths of the surface horizons, generally 5-15 cm for the surface and 10-20 cm for the subsurface, often deeper.

Notable features include:

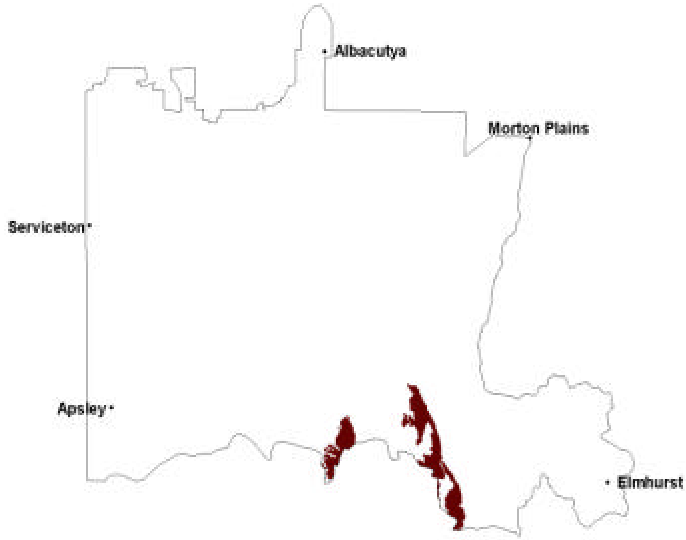
- Gradational or uniform change in clay percentage with depth.
- Variable depth to parent material (may be shallow).
- Occasional indurated or accumulation zones with in the predominantly coarse soil (Podosols).
- These soils have low nutrient capacity and low water holding capacity.
- These features make these soils vulnerable to erosion, particularly on sloping terrain given low consistence/coherence and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA54 | Grampians Ranges | Hillslope | Bleached-Leptic Tenosol | Gn1.84/ Uc2.21 | T7324 - HORSHAM |
| GRAMP lith* | Grampians Ranges | Hillslope | Acidic, Lithic, Leptic Rudosol | Uc5.11 | Unknown |

* Refers to the lithosol description (no site identification provided) on page 185 (Appendix 1A) of the Grampians landsystem report (Sibley 1967).

## 14. Sandy gradational soils/Strike ridges and valleys: Cuesta landscapes




These soils have developed on mainly Palaeozoic sandstone and colluvial material in the Western Uplands, primarily the Grampian Ranges. These soils are a heavier than Type 13, but have a comparative coarse sand component and are of minor occurrence.

The surface soil is usually a grey or brown loamy sand to sandy loam, which is weakly structured. It overlies a conspicuously bleached loamy sand to sandy clay loam subsurface horizon. This is massive to weakly structured with many coarse grained quartz sand. There may be a gradual to clear change to a yellow brown silty or clay loam subsoil horizon, with moderate medium structure (with medium sized peds) or sandy clay loam subsoil, which is weakly structured. This often has few to common quartz or rock fragments or grades directly into weathered sandstone parent material. The profile depth is about 70 cm or more with variable depths of the surface horizons, generally 5-15 cm for the surface and 10-20 cm for the subsurface, often deeper.

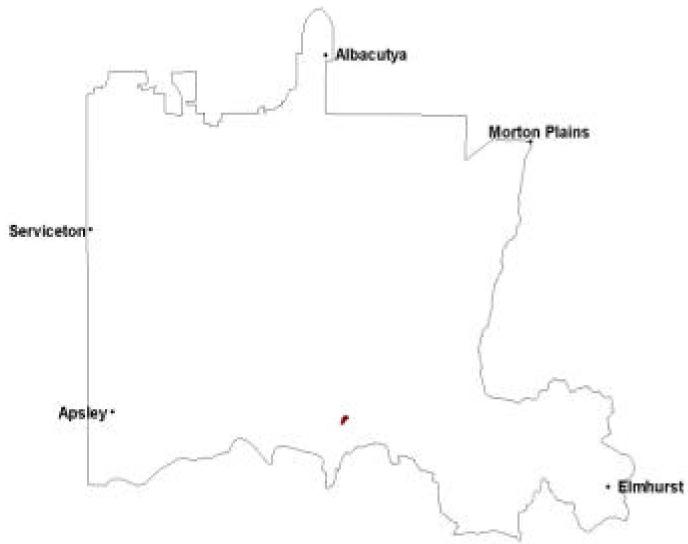
Notable features include:

- Gradational or uniform change in clay percentage with depth.
- Occasional indurated or accumulation zones with in the predominantly coarse soil (Podosols).
- These soils have with low nutrient holding capacity and low water holding capacity.
- These features make these soils vulnerable to erosion, particularly on sloping terrain given low consistence/coherence and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA54 | Grampians Ranges | Hillslope | Basic, Lithic, Yellow-Orthic, Tenosol | Gn2.21 | T7324 - HORSHAM |
| GRAMP335 | Grampians outwash slopes | Hillslope | Acidic, Mesotrophic, Brown Kandosol | Gn2.21 | T7323 - GRAMPIANS |

## 15. Sandy soils with pans/Strike ridges and valleys: Sandstone hills, valleys




These soils have developed on mainly associated colluvial material of Palaeozoic sandstone in the Western Uplands, primarily the Black Range as well as the Grampians Ranges. This is a strongly acidic soil tending to slightly acidic/neutral at depth.

The surface soil is usually a dark brownish grey loamy sand, which is apedal (sandy) and has very weak consistence (strength). It clearly overlies a conspicuously bleached pale loamy sand subsurface horizon, which is apedal (sandy). This soil also has very weak consistence (strength). There is a clear change to a yellow organic and sesquioxide discontinuous pan (coffee rock) sitting clearly over a mottled (yellow) medium clay, which is massive. This grades into lighter textured weathered material. The profile depth is about 130 cm or more with variable depths of the surface horizons, generally 15-30 cm for the surface and 20-30 cm for the subsurface, often deeper.

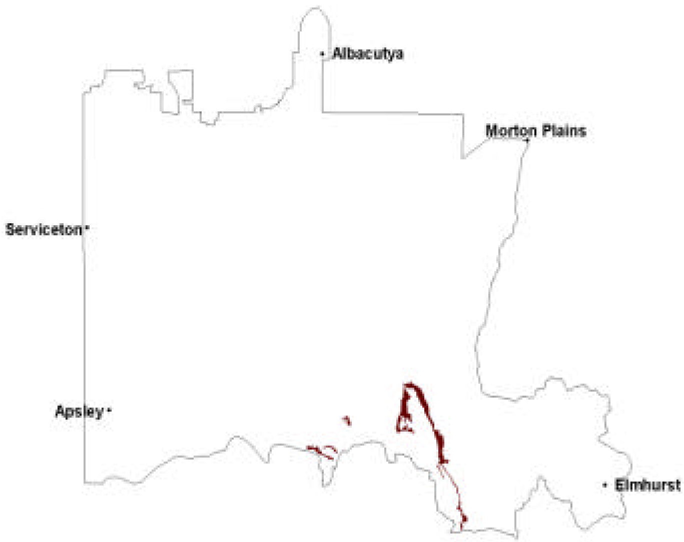
Notable features include:

- Deep uniform sands over a pan, in turn over variable amounts of clay at depth.
- Pan type, depth (up to 40 cm at site example) and continuity will vary.
- These soils have low nutrient capacity and low water holding capacity.
- These features make these soils vulnerable to sheet and wind erosion, particularly on sloping terrain given low consistence/coherence and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| ALRA66 | Grampians plains | Hillslope | Humisesquic, Parapanic, Aeric Podosol | Uc2.31 | T7423 - ARARAT |

## 16. Acidic, grey texture contrast soils (sandy surfaces)/Strike ridges and valleys: Sandstone hills




These soils have developed on mainly associated colluvial material of Palaeozoic sandstone in the Western Uplands, primarily the Black Range as well as the Grampians Ranges. This is a strongly acidic soil, more so at depth in one instance.

The surface soil is usually a dark loamy sand, which is weakly structured and has weak consistence (strength). It clearly overlies a conspicuously bleached pale loamy sand subsurface horizon, which is massive. This has weak consistence (strength). There is a clear change to a (yellow and occasionally red) mottled light grey, heavy silty clay loam to light medium clay. This has moderate structure (with coarse parting to medium sized peds). This soil grades into lighter textured weathered material with very few fine quartz. The profile depth is about 120 cm or more with variable depths of the surface horizons, generally 5 cm for the surface and 15 cm for the subsurface, often deeper.

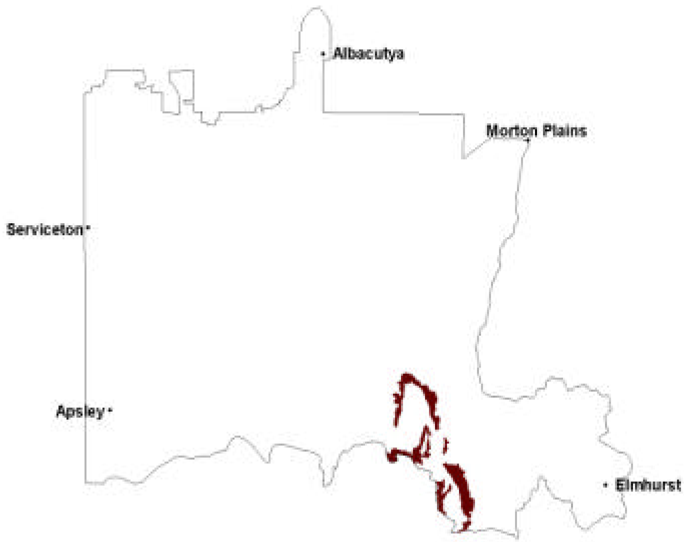
Notable features include:

- Texture contrast soil, variable depth sandy upper soil over yellow and red-brown mottled pale clay.
- The upper soil has low nutrient holding capacity and low water holding capacity.
- These features make these soils vulnerable to sheet and wind erosion, particularly on sloping terrain, given low consistence/coherence and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA55 | Grampians outwash slopes | Hillslope | Bleached-Mottled Mesotrophic, Grey Kurosol | Dy5.41 | T7324 - HORSHAM |

## 17. Brown and yellow texture contrast soils (sandy surfaces)/Strike ridges and valleys: Terraces and floodplains




These soils have developed on mainly associated alluvial and colluvial material of Palaeozoic sandstone in the Western Uplands, primarily in the Victoria Valley. This soil is generally slightly acidic throughout.

The surface soil is usually a dark greyish brown loamy sand, which is massive and has weak consistence (strength) or sometimes a hardsetting surface. It clearly overlies a conspicuously bleached yellow loamy sand subsurface horizon, which is massive and has weak consistence (strength). There is a clear change to a (red and yellow-brown) mottled yellow medium clay. This is strongly structured (coarse parting to medium sized peds) with few ferruginous nodules and some quartz or rock fragments, grading into lighter textured mottled clay with weathered sandstone fragments. The profile depth is about 100 cm or more with variable depths of the surface horizons, generally 15 cm for the surface and 20-30 cm for the subsurface, often deeper.

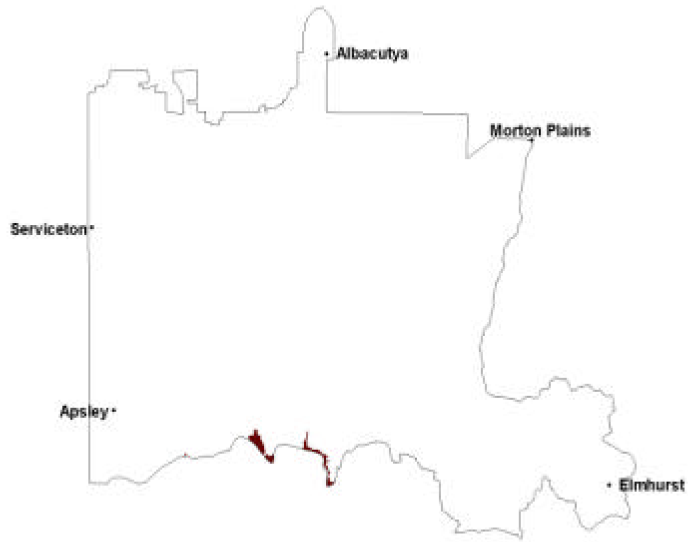
Notable features include:

- Texture contrast soil, hardsetting or non-hardsetting surface.
- Bleached subsurface soil often with some ferruginised nodules (buckshot).
- Mottled pale subsoil has restricted soil drainage, often sodic at depth.
- The upper soil has low nutrient capacity and limited water holding capacity.
- These features make these soils vulnerable to sheet and wind erosion, particularly on sloping terrain given low consistence/coherence and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| DOAHG6 | Grampians plains | Hillslope | Bleached-Mottled, Mesotrophic, Brown Chromosol | Dy5.41 | T7423 - ARARAT |
| DOAHG7 | Grampians plains | Hillslope | Melacic-Mottled, Magnesic, Brown Chromosol | Dy3.81 | T7423 - ARARAT |
| DOAHG5 | Grampians plains | Hillslope | Bleached-Mottled, Mesotrophic, Brown Chromosol | Dy3.41/ Dy5.41 | T7423 - ARARAT |

## 18. Sodic brown and yellow texture contrast soils (sandy surfaces)/Low elevation plateaux: High relief, low drainage density and Low relief, low drainage density




These soils have developed on mainly of Neogene sands (often indurated) and associated colluvial material in the Western Uplands, predominantly on the Dundas Tableland.

The surface soil is usually a dark loamy sand, which is weakly structured and has weak consistence (strength). It clearly overlies a conspicuously bleached pale loamy sand subsurface horizon, which is massive and has weak consistence (strength). There is a clear change to a (brown, brown and red) mottled yellow or yellowish brown medium to heavy clay. This soil has strong structure (with coarse to medium ped size) and some quartz or ironstone fragments. This grades into lighter textured weathered material of clay and ferruginised sandstone. The profile depth is about 120 cm or more with variable depths of the surface horizons, generally 15 cm for the surface and 20 cm for the subsurface, shallower on upper topographic positions.

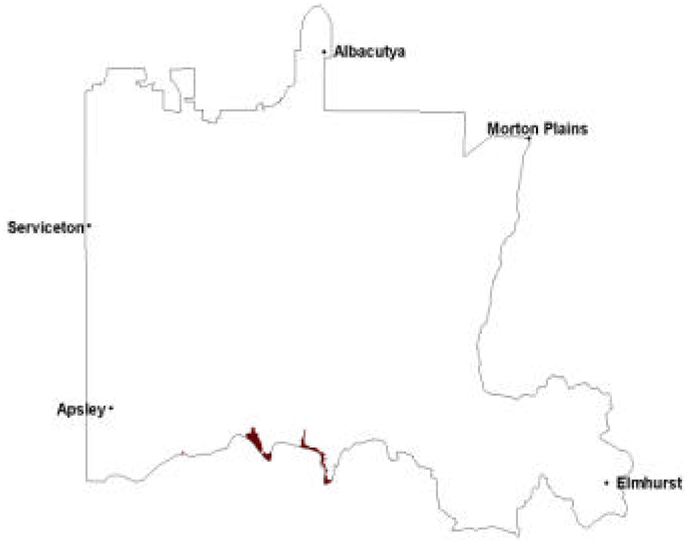
Notable features include:

- Texture contrast soil, hardsetting or non-hardsetting surface.
- Bleached subsurface soil, often with some ferruginised nodules (buckshot).
- Mottled subsoil has restricted soil drainage, often sodic at depth.with ferruginised material at depth and can have some calcium carbonate at depth.
- The upper soil has low nutrient capacity and depth limited water holding capacity.
- These features make these soils vulnerable to sheet, wind erosion and compaction, given low consistence/coherence and lighter surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA136 | Balmoral undulating plain | Footslope | Bleached-Vertic (& Sodic), Eutrophic, Brown Chromosol | Dy5.43 | T7223 - BALMORAL |

## 19. Brown and yellow texture contrast soils/Low elevation plateaux: High relief, low drainage density and Low relief, low drainage density




These soils have developed on weathered material of Neogene sands (often indurated) in the Western Uplands, predominantly on the Dundas Tableland. The soil is acidic throughout.

The surface soil is generally a dark greyish brown sandy loam, which is weakly structured. This soil grades into a subsurface horizon, occasionally bleached. There is a clear, wavy change to a dark yellowish brown, light medium to medium clay. This has weak structure (with fine sized peds), becoming with depth, more yellow and mottled in colour with ferruginous and manganiferous concretions/nodules. This soil grades into the ferruginous rich discontinuous pan material which abruptly overlies a red and pale horizontal mottled layer. The depth is about 80-100 cm or more with variable depths of the surface horizons, generally 20 cm for the surface and 10 cm for the subsurface, occasionally deeper.

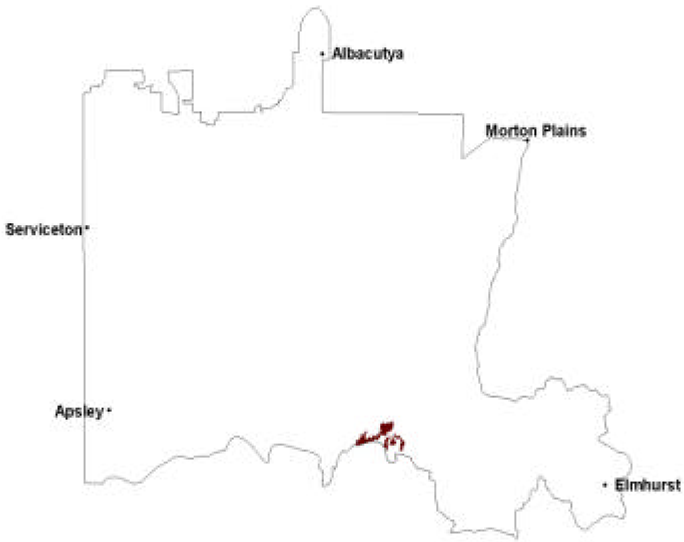
Notable features include:

- Texture contrast soil, acidic but not strongly at depth.
- A ferric pan as well as ferruginous concretions/nodules are generally present.
- Roots tend to be confined to upper soil.
- Weathered substrate material often displays distinctive red and white horizontal mottling (tiger mottles).
- The ferruginised pan and coarse mottled material indicate restricted drainage.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| GL164 | Balmoral undulating plain | Flat | Mottled, Petroferric, Brown Chromosol | Dy3.21/ Dy3.41 | T7223 - BALMORAL |

## 20. Cracking clay soils/Low elevation plateaux: Low relief, low drainage density




These soils have developed on associated alluvium and colluvial material of Neogene sands (often indurated) in the Western Uplands, predominantly on the Dundas Tableland. The soil has an acidic surface but the subsoil is alkaline not far below the surface horizon.

The surface soil is usually a dark (occasionally self-mulching) light to light medium clay which is structured. This may overlie an occasional bleached subsurface horizon. These soils have strong consistence (strength) depending on moisture condition. There is a clear change to a dark grey, heavy clay. It has strong structure (with medium parting to fine sized peds), becoming more yellow in colour and with slickensides at depth. This soil grades into lighter textured weathered alluvium parent material. The profile depth is about 180 cm or more with variable depths of the surface horizons, generally 5 cm for the surface and 10 cm for the subsurface, occasionally deeper.

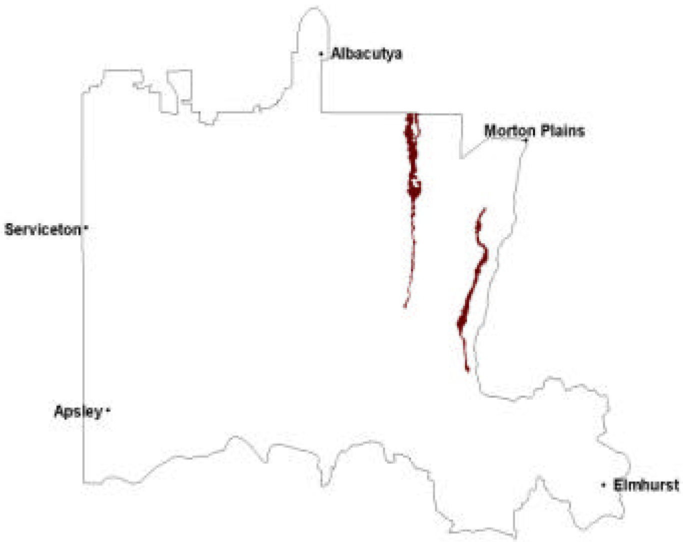
Notable features include:

- Cracking clay soil, variable surface friability (coarser pedality).
- Strong consistence (strength) when dry.
- Occasional ferruginised nodules (buckshot) and calcium carbonate at depth.
- Yellow hued subsoil has restricted soil drainage, generally sodic at depth.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA 137 | Balmoral undulating plain | Footslope | Endocalcareous-Endohypersodic, Epipedal, Grey Vertosol | Ug5.28 | T7223 - BALMORAL |

## 21. Sodic, grey texture contrast soils/Modern floodplains: Meander belt below flood level




These soils have developed on alluvium of Recent unconsolidated material in the North West Dunefields and Plains, predominantly on the Wimmera River floodplain. This soil has a slightly acidic to neutral surface, grading to alkaline in the subsoil.

The surface soil is usually a grey sandy clay loam. It is weakly structured and hardsetting. It occasionally overlies a bleached subsurface horizon, generally thin. There is a clear change to a grey (occasionally light grey) light clay. This is weakly structured (coarse ped size) and sodic. At depth this grades into alluvial regolith. The sodicity increases with depth and minor carbonate nodules are visible below the upper subsoil. The profile depth is 2 m or more with variable depths of the surface horizons (generally 5-10 cm for the topsoil) and 10 cm for the subsurface (A2 horizon).

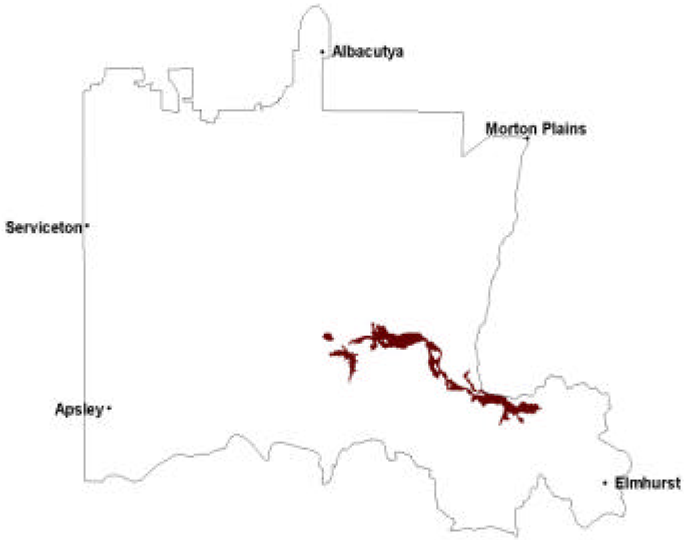
Notable features include:

- Texture contrast soil, variable surface friability (generally hardsetting).
- Strong consistence (strength) when dry.
- This soil has subplastic subsoil and likely to be vertic.
- The pale subsoil indicates poor drainage, often sodic at depth.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WIA20 | Wimmera River | Terrace flat | Calcic, Subnatric, Grey Sodosol | Dy3.33 | T7324 - HORSHAM |

## 22. Cracking clay soils/Modern floodplains: Meander belt below flood level




These soils have developed on alluvium of Recent unconsolidated material in the Northern Riverine Plains, predominantly on the Wimmera River floodplain. The soil has a slightly acidic surface becoming neutral and then more acidic with depth.

The surface soil is usually a light clay, massive (occasionally weakly structured). It occasionally overlies a bleached subsurface horizon. These soils have strong consistence (strength) depending on moisture condition. There is a clear change to a grey (occasionally light grey) heavy clay (occasionally light medium upper subsoil). It has moderate structure (with coarse to medium ped size) and often with very few carbonate nodules or soft segregations. This grades into lighter textured weathered alluvial parent material. The profile depth is about 160 cm or more with variable depths of the surface horizons, generally 5 cm for the surface.

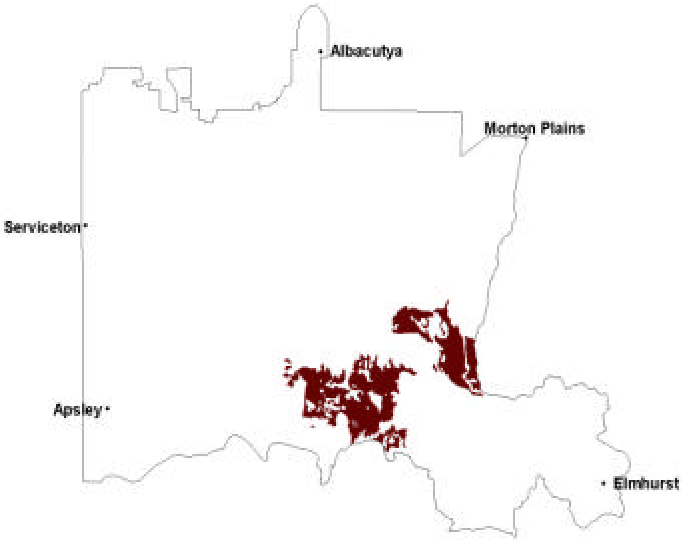
Notable features include:

- Cracking clay soil, variable surface friability (massive or weak to moderate structure on cultivation).
- Strong consistence (strength) when dry; workability is more difficult than for than self-mulching soils.
- Whole coloured (grey) but has restricted soil drainage.
- Sodic subsoil, often strongly sodic at depth, but acidic trend at depth.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WIA22 | Wimmera River | Terrace flat | Endocalcareous-Endohypersodic, Massive, Grey Vertosol | Ug5.24 | T7324 - HORSHAM |

## 23. Cracking clay soils/Older alluvial plains: Plains with and without leveed channels and Alluvial fans and aprons




These soils have developed on alluvium of Quaternary unconsolidated material in the Northern Riverine Plains, predominantly on the Wimmera River older alluvial plains (with and without prior streams). This soil is alkaline throughout.

The surface soil is usually a light to medium clay, usually structured (occasionally massive). These soils have strong consistence (strength) depending on moisture condition. There is a clear change to a dark grey (occasionally grey) heavy clay. This has moderate structure (with coarse size peds), subplastic often with few calcium carbonate nodules throughout the profile. The subsoil has slickensides indicating high shrink-swell characterisitics. This often grades into lighter textured alluvial material at depth. The profile depth is about 160 cm or more with variable depths of the surface horizons, generally 5 cm for the surface.

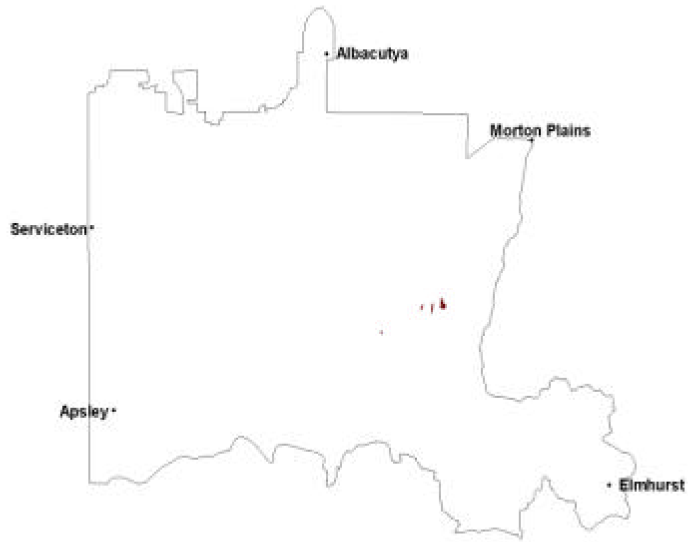
Notable features include:

- Cracking clay soil, variable surface friability (may be massive or slightly self-mulching).
- Strong consistence (strength) when dry.
- The surface soil is subplastic and the subsoil is sodic, strongly at depth and has vertic properties.
- The paler, yellower hued subsoil has restricted soil drainage.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WIA11 | Murtoa flats | Plain | Epicalcareous-Endohypersodic, Epipedal, Grey Vertosol | Ug5.28 | T7324 - HORSHAM |
| WIA12 | Longerenong prior stream plains | Plain | Endocalcareous-Endohypersodic, Epipedal, Grey Vertosol | Ug5.29 | T7324 - HORSHAM |
| WIA17 | Drung alluvial plain | Plain | Endohypersodic, Epipedal, Grey Vertosol | Ug5.24 | T7324 - HORSHAM |
| HOR04 | Horsham south sand-clay plain | Plain | Episodic, Epipedal, Grey Vertosol | Ug5.24 | T7324 - HORSHAM |

## 24. Cracking and self-mulching clay soils/Older alluvial plains: Plains with and without leveed channels




These soils have developed on alluvium of Quaternary unconsolidated material in the Northern Riverine Plains, predominantly on the Wimmera River prior stream plains. This soil is alkaline throughout.

The surface soil is a dark greyish brown light to medium clay, which is subplastic and self-mulching (occasionally moderately structured). These upper soils have strong consistence (strength) depending on moisture condition. There is a clear change to a dark grey (occasionally grey) medium to heavy clay. This upper subsoil is weakly structured (fine sized peds) but coarsely structured below the upper subsoil. It is subplastic, often with calcium carbonate and is sodic (occasionally high in the profile). The profile depth is about 2 m or more grading into fine alluvial sediments with variable depths of the surface horizons, generally 5-15 cm for the surface soil.

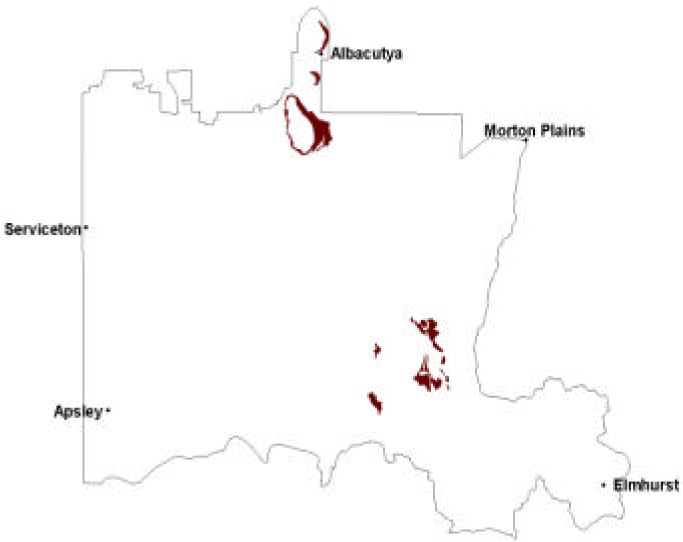
Notable features include:

- Cracking clay and self-mulching soil, variable surface friability (mainly self-mulching).
- Strong consistence (strength) when dry.
- The soil is sodic, occasionally including the surface and strongly sodic at depth, as well as some calcium carbonate nodules and soft segregations.
- Restricted drainage when moist (shrink-swell, slickensides).

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WIA10 | Longerenong prior stream plains | Plain | Endocalcareous-Endohypersodic, Self-Mulching, Grey Vertosol | Ug5.24 | T7324 - HORSHAM |
| WIA19 | Longerenong prior stream plains | Plain | Episodic-Endocalcareous, Self-Mulching, Grey Vertosol | Ug5.24 | T7324 - HORSHAM |
| WIA33 | Wimmera River | Plain | Epicalcareous, Self-Mulching, Grey Vertosol | Ug5.5 | T7324 - HORSHAM |

## 25. Sodic, red texture contrast soils/Older alluvial plains: Plains with and without leveed channels




These soils have developed on alluvium of Quaternary unconsolidated material in the Northern Riverine Plains, predominantly on the Wimmera River older alluvial plains (with and without prior streams). Some soils may be gradational and brown in places. The soil is slightly acidic at the surface but becomes alkaline just above or in the subsoil.

The surface soil is usually a dark yellowish brown sandy clay loam, which is weakly structured. This often overlies a bleached subsurface horizon, which is massive and just above the subsoil. There is a clear change to a yellowish red (occasionally brown) medium sodic clay. This is weakly structured (coarse sized peds, sometimes columnar). This grades into lighter textured, mottled lower subsoil often with calcium carbonate soft segregations or nodules, and occasional heavier regolith or buried soils. The profile depth is about 180 cm or more with variable depths of the surface horizons, generally 5 cm for the surface and 15 cm for the subsurface, occasionally deeper.

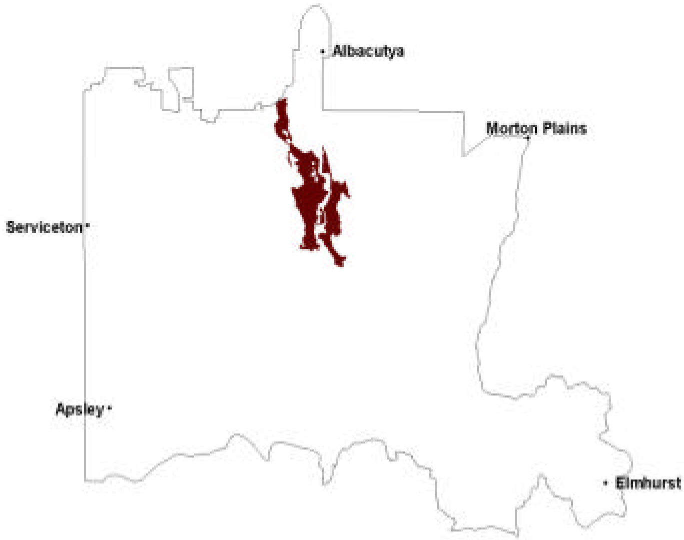
Notable features include:

- Texture contrast soil, generally low surface friability (generally hardsetting).
- Weak upper soil consistence, but very strong lower subsurface and upper subsoil consistence (strength) when dry).
- Mottled subsoil only at depth; slightly restricted soil drainage.
- Soils often sodic at depth, if not sodic in upper subsoil.
- Occasional brown subsoil variants.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WIA16 | Longerenong prior stream plains | Levee | Calcic, Mesonatric, Red Sodosol | Dr2.43 | T7324 - HORSHAM |
| WIA14 | Longerenong prior stream plains | Plain | Calcic, Subnatric, Red Sodosol | Dr2.33 | T7324 - HORSHAM |
| WLRA105 | Drung alluvial plain | Terrace | Bleached-sodic, Eutrophic, Red Chromosol | Dr2.42 | T7424 - RUPANYUP |

## 26. Calcareous gradational soils/Calcareous dunefields: Linear dunes subdominant




These soils have developed on Quaternary unconsolidated material in the North West Dunefields, particularly with linear dunefields. The soil is alkaline and calcareous throughout.

The surface soil is usually a very dark greyish brown clay loam (sandy), which is weakly structured (coarse sized peds).

This abruptly and clearly overlies a reddish yellow light clay. This is moderately structured (medium sized peds) with calcium carbonate soft segregations (weaker structure with greater calcium carbonate). This soil grades into a heavier redder lower subsoil, with moderate structure and with calcium carbonate soft segregations and manganese flecks. The profile depth is about 150 cm or more with variable depths of the surface horizons, generally 10-15 cm for the surface, occasionally deeper.

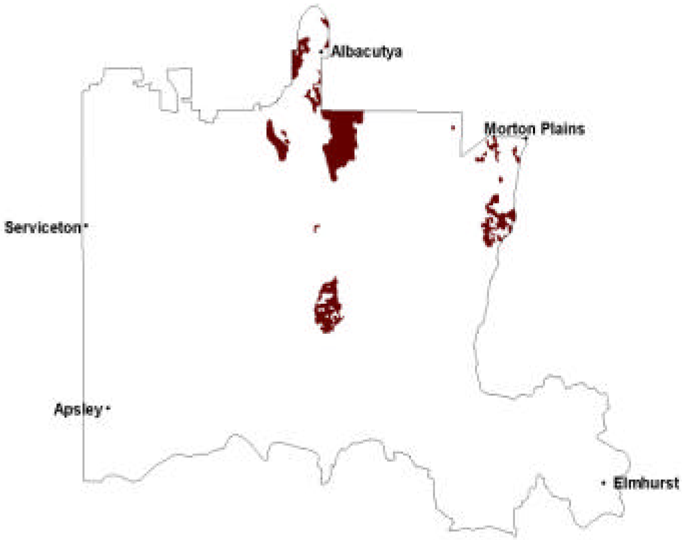
Notable features include:

- Gradational profile with a heavier textured subsoil at depth.
- Highly calcareous upper soil with some free carbonate but high exchangeable sodium and soluble salts at depth.
- Limited surface friability (generally hardsetting), strong consistence (strength) when dry.
- Sodic, often strongly at depth, restricting drainage but reddish colours would indicate slight restriction to water movement.
- Occasional brown subsoil variants.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| TopCrop4 | Dimboola rises | Plain | Endohypersodic, Pedal, Hypocalcic Calcarosol | Gc2.2 | T7325 - WARRACKNABEAL |

## 27. Sodic, red texture contrast soils/Calcareous dunefields: Linear dunes subdominant, Hummocky dunes subdominant and Plains




These soils have developed on Quaternary unconsolidated material, generally of aeolian origin in the North West Dunefields and Plains, in the north of the WCMA. The soils are neutral to alkaline in the surface and alkaline and calcareous in the subsoil.

The surface soil is usually a dark brown sandy loam to sandy clay loam, with weak structure. It occasionally overlies a bleached subsurface horizon. The contact with the subsoil will often have strong consistence (hard). There is a clear change to a dark red to yellowish red (occasionally yellowish brown) medium clay. It has strong structure (with coarse parting to medium sized peds). With depth there is less structure and clay content, grading into lighter textured highly calcareous material, with weak structure. Some soils may have yellow subsoils with red mottling or red deep subsoil. The profile depth is about 120 cm or more with subtle change into unconsolidated regolith or less alkaline clay on less alkaline parent material, with variable depth of the surface horizon, generally 10-15 cm.

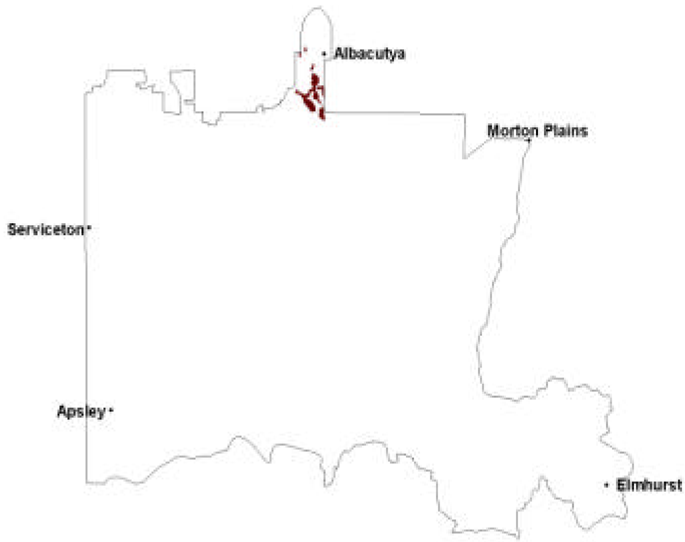
Notable features include:

- Texture contrast soil, variable surface friability (generally hardsetting).
- Strong consistence of lower surface and upper subsoil (strength) when dry.
- Occasional sporadic bleached subsurface soil.
- Decreasing pedality of subsoil with depth, with increasing calcium carbonate content.
- Occasional brown or yellow subsoil variants.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| TopCrop2 | Dimboola rises | Plain | Hypercalcic, Mesonatric, Red Sodosol | Dr3.13 | T7325 - WARRACKNABEAL |
| LS17 | Perenna undulating sand plains and rises | Dunecrest | Hypercalcic, Mottled-Subnatric, Yellow Sodosol | Dy3.43 | T7225 - NHILL |
| TopCrop1 | Hopetoun rises and swales | Plain | Hypercalcic, Subnatric, Red Sodosol | Dr2.13 | T7325 - WARRACKNABEAL |
| WIA3 | Murra Warra East gentle rises | Plain | Calcic, Subnatric, Red Sodosol | Dr2.33 | T7424 - RUPANYUP |

## 28. Sodic, yellow and grey texture contrast soils/Calcareous dunefields: Linear dunes subdominant, Hummocky dunes subdominant




These soils have developed on Quaternary unconsolidated material, generally of aeolian origin in the North West Dunefields and Plains, in the north of the region. The soil has a neutral to alkaline surface over a strongly alkaline subsoil.

The surface soil is a yellowish brown to light yellowish brown loamy sand, with apedal (sandy) to weak structure. It overlies a bleached fine sand subsurface horizon, which is apedal (sandy). There is a sharp/abrupt change to a mottled yellow brown (occasionally brown) sandy clay loam to medium clay, often with a red mottle. This is strongly structured (with coarse parting to medium sized peds). This may grade into a lighter calcareous horizon before grading into a sodic medium clay at depth. Some soils may have yellow subsoils with red mottling or red/brown deep subsoil. The profile depth is about 150 cm or more with slightly variable depths of the surface horizons, generally 10 cm for the surface and 5 cm for the subsurface, often deeper.

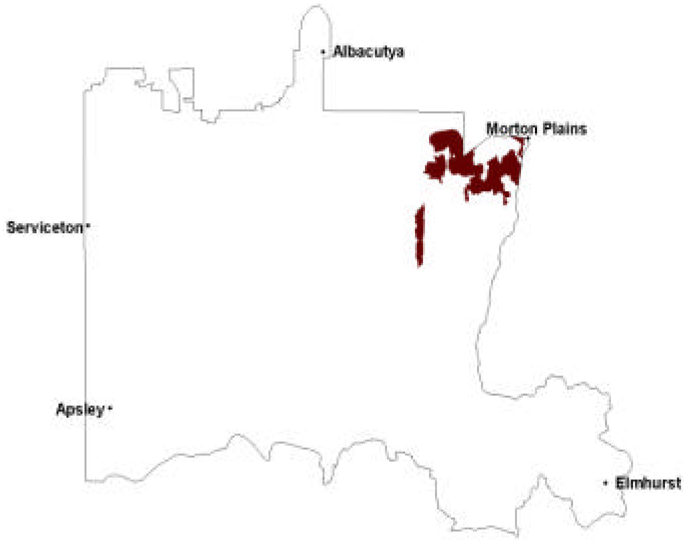
Notable features include:

- Texture contrast soil, variable surface friability (generally can be soft or slightly hardsetting).
- Strong consistence of the subsoil (strength) when dry.
- Occasional bleached subsurface soil.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| LS17 | Perenna undulating sand plains and rises | Dunecrest | Hypercalcic, Mottled-Subnatric, Yellow Sodosol | Dy3.43/ Dy5.43 | T7225 - NHILL |
| WAR33 | Hopetoun rises and swales | Plain | Melanic, Hypernatric, Yellow Sodosol | Dy2.13 | T7325 - WARRACKNABEAL |
| WLRA128 | Charlton gentle rises | Plain | Hypercalcic, Mottled-Subnatric, Yellow Sodosol | Dy2.13 | T7425 - DONALD |

## 29. Cracking clay soils/Calcareous dunefields: Hummocky dunes subdominant, Linear dunes subdominant




These soils have developed on Quaternary unconsolidated material, generally of aeolian and lacustrine origin in the North West Dunefields and Plains, in the north of the WCMA region. These soils occupy the plains and swales, and may occur in association with vertic sodic texture contrast soils (i.e. sodosols). This distribution of soils can relate to gilgai microrelief e.g. gilgai.

The surface soil is often a dark pedal (often self-mulching) fine sandy clay loam to light clay. It occasionally overlies a bleached subsurface horizon. There is a clear change to a dark grey (occasionally dark greyish brown) light to medium clay subsoil horizon. This is vertic (cracking and usually slickensides) and strongly structured (coarse parting to fine sized peds). This grades into a heavier horizon, becoming heavier with depth and less obvious fine structure, but slickensides may be present. Calcareous material (carbonate) may be visibly present only in the deeper soil but the profile may still be calcareous throughout. Colour may or may not lighten within a metre depth (indicating restricted drainage). The profile depth is about 150 cm or more grading into sediments, with variable depths of the surface horizons, generally 15 cm for the surface.

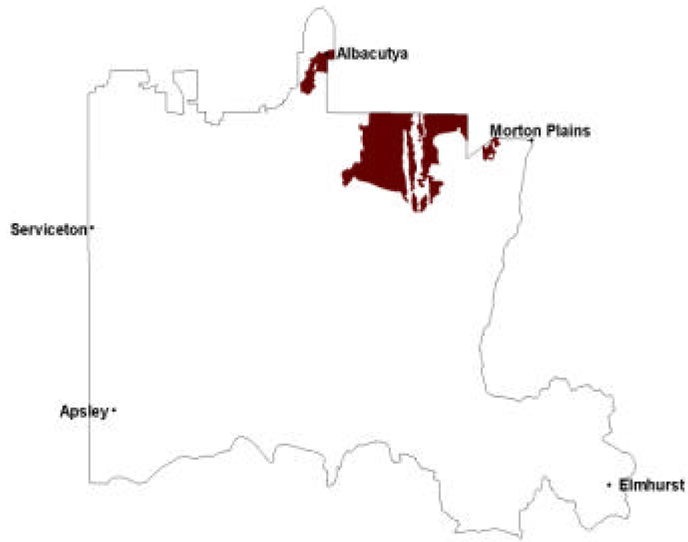
Notable features include:

- Cracking clay soil, variable surface friability/surface condition (pedal or self-mulching).
- Strong consistence (strength) when dry.
- Occasional bleached subsurface horizon.
- Mottled or yellower subsoil has more restricted soil drainage.
- The soils are often sodic at the surface and strongly sodic at depth with manganiferous material (usually flecks or small concretions).

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA126 | Charlton gentle rises | Plain | Episodic-Epicalcareous, Self-Mulching, Grey Vertosol | Ug5.28 | T7425 - DONALD |
| WLRA127 | Charlton gentle rises | Plain | Episodic-Endocalcareous Epipedal, Grey Vertosol | Ug5.28 | T7425 - DONALD |

## 30. Calcareous gradational soils/Calcareous dunefields: Hummocky dunes subdominant




These soils have developed on Quaternary unconsolidated material in the North West Dunefields, particularly with hummocky dunefields including lunettes. This is a minor soil type for this land type.

The surface soil is usually a dark brown sandy clay loam, which is apedal (massive) to weakly structured. It occasionally overlies a weakly structured subsurface transitional horizon. There is a clear change to a dark greyish brown to yellowish red, light clay subsoil horizon. This is weakly to moderately structured (with coarse parting to medium sized peds). This soil grades with depth into decreasing structure (pedality) with increasing calcium carbonate soft segregations. This grades into a heavier textured yellowish red clay which is structured, which in turn grades into lighter textured browner clayey material with slickensides (less aerated) at depth. The profile depth is about 150 cm or more, grading into unconsolidated material (regolith) with variable depths of the surface horizons, generally 5-10 cm for the surface and 15 cm for the subsurface, where it occurs.

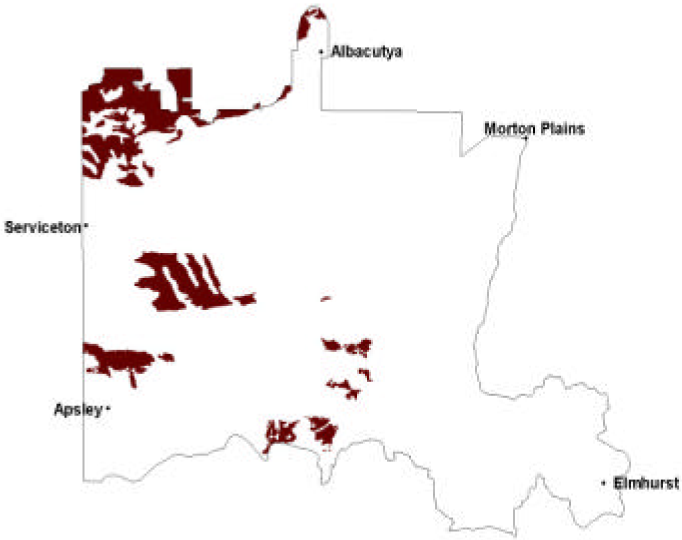
Notable features include:

- Gradational soil, calcareous throughout with highly calcareous upper soil with some free carbonate but high sodium and salts at depth.
- Variable surface friability (generally hardsetting, weak strength).
- Weaker consistence (strength) with high free carbonate.
- Occasional manganiferous flecks at depth.
- Noticeable increase in clay at depth, slickensides (vertic), browner and mottled and more restrictive drainage.
- Generally strongly sodic at depth (and likely to be dispersive), occasionally sodic at the surface.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA130 | Hopetoun rises and swales | Plain | Epihypersodic, Marly, Hypercalcic Calcarosol | Gc1.2 | T7325 - WARRACKNABEAL |
| WLRA15 | Hopetoun rises and swales | Plain | Epibasic, Pedal, Calcic Calcarosol | Gc2.2 | T7325 - WARRACKNABEAL |
| WLRA13 | Hopetoun rises and swales | Plain | Endohypersodic, Pedal, Calcic Calcarosol | Gc2.2 | T7325 - WARRACKNABEAL |

## 31. Sandy soils with and without pans/Siliceous dunefields: Parabolic and linear dunes




These soils have developed on Quaternary unconsolidated material (mainly aeolian) in the North West Dunefields, particularly the siliceous dunefields including parabolic and linear dunes.

The surface soil is usually a brown sand to loamy sand, which is apedal. This grades into a deep sand subsurface horizon, which is apedal (sandy) and conspicuously bleached. There is a clear to gradual change to a darker (brown) sandy subsoil horizon, which is apedal (massive) and has organic and iron/aluminium concentrations (humosesquic). There is a clear change to a mottled brownish yellow (occasionally light grey) coarse sandy clay loam to sandy clay. This is weakly structured and acidic, often with very pale brown and dark reddish brown mottles and some quartz gravel. This soil grades into lighter textured weathered material or regolith. The profile depth is about 150 cm or more with variable depths of the surface horizons, generally 10-15 cm for the surface and 70 cm for the subsurface, often deeper. The pan is about 20-40 cm thick.

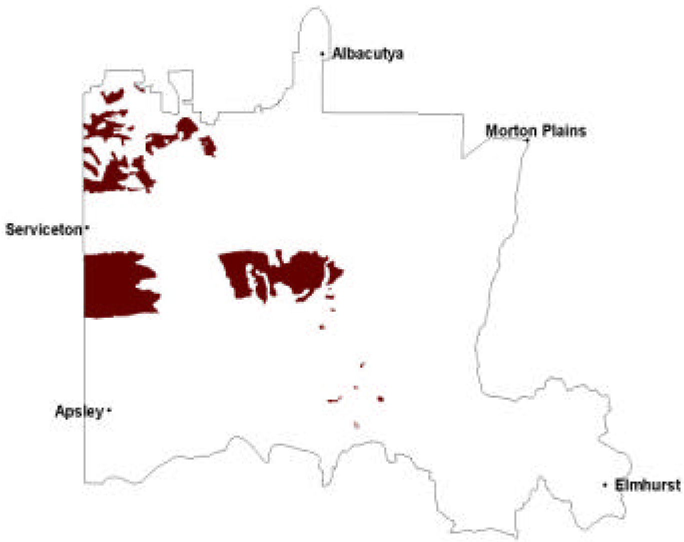
Notable features include:

- Gradational or limited (uniform) change in clay percentage with depth.
- There may be a mottled clayey base at depth (deep Sodosol).
- There may be occasional indurated or accumulation zones with in the predominantly coarse soil (Podosols).
- Despite neutral to slightly alkaline pH these soils have low nutrient capacity and low water holding capacity.
- These soils are susceptible to wind and sheet erosion, particularly on sloping terrain given weak consistence (strength)/low coherence and lighter textured surface materials.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA74 | Big Desert jumbled dunes | Plain | Basic, Arenic, Bleached-Orthic Tenosol | Uc2.31 | T7225 - NHILL |
| WLRA85 | Big Desert dense dunes | Duneslope | Fragic, Humosesquic, Aeric Podosol | Uc2.32 | T7124 - GOROKE |

## 32. Sodic, yellow and grey texture contrast soils/Siliceous dunefields: Parabolic and linear dunes




These soils have developed on Quaternary unconsolidated material, generally of aeolian origin in the North West Dunefields and Plains, in swales, flats or plains amongst the dunefields. Soils are generally whole coloured, but some may have yellow subsoils with red mottling or red/brown deep subsoil. The soils have acidic surfaces with alkaline subsoils.

The surface soil is usually a dark greyish brown loamy sand to sandy loam, which are apedal (sandy) and have loose consistence. This soil occasionally overlies a loamy sand to sandy clay subsurface horizon, which is bleached and apedal either sandy or massive. There is a clear change to a light yellowish brown (occasionally brownish yellow, yellow or light grey) medium to heavy sodic clay upper subsoil. This is strongly structured (with coarse parting to medium sized peds), often with a reddish yellow mottle. This grades into similar material with few carbonate and manganese segregations and is less well structured. This soil then grades into a paler medium to heavy clay, strongly mottled, with slickensides and occasionally with weathered sandstone. The profile depth is about 120 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 5-15 cm for the subsurface, occasionally deeper.

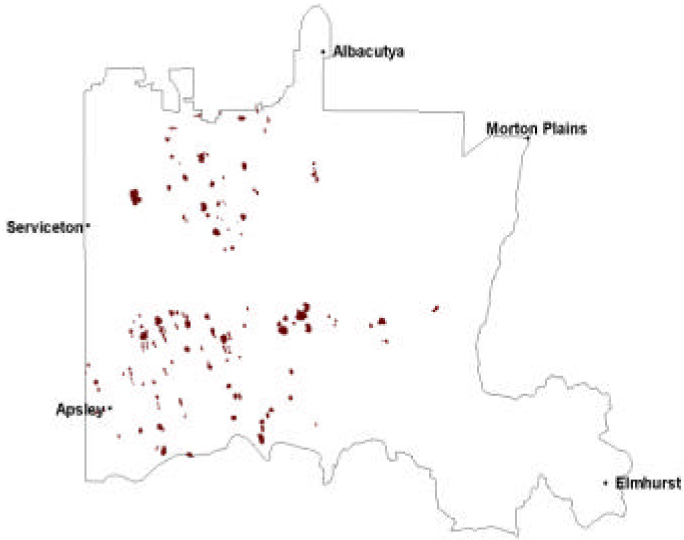
Notable features include:

- Texture contrast soil, variable surface friability (generally sandy and soft but can be hardsetting).
- Occasional bleached subsurface soil (may be loose or cemented).
- Mottled subsoil strong consistence (strength) when dry, has restricted soil drainage as strongly sodic at depth.
- Subsoils are calcareous but few carbonate segregations.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| LSWW8 | Big Desert dense dunes | Riseslope | Hypercalcic, Mottled-Subnatric, Yellow Sodosol | Dy5.43 | T7125 - KANIVA |
| LSWW7 | Big Desert dense dunes | Riseslope | Hypercalcic, Mottled-Subnatric, Grey Sodosol | Dy3.43 | T7125 - KANIVA |
| WIA24 | Quantong dunes and swales | Dune | Calcic, Mottled-Mesonatric, Yellow Sodosol | Dy3.43 | T7324 - HORSHAM |
| WIA31 | Quantong dunes and swales | Swale | Calcic, Mottled-Mesonatric, Yellow Sodosol | Dy2.33 | T7324 - HORSHAM |

## 33. Seasonally wet soils; Sodic, yellow and grey texture contrast soils/Depressions: Saline depressions




These soils have developed on Recent unconsolidated material, generally of riverine origin in the North West Dunefields and Plains, in swales, flats or plains and occasional sandsheets of the Douglas Depression. Some soils may have yellow subsoils with red mottling or red/brown deep subsoil. Calcareous gradational soils (often red) also occur.

The surface soil is usually a brown sandy to sand to loamy sand. This is apedal to weakly structured. It abruptly overlies a light yellowish brown fine sand subsurface horizon, which is bleached. There is a clear change to a yellow brown (occasionally light grey) sandy clay to medium clay subsoil horizon. This is weakly (sandy) or moderately structured (coarse to medium sized peds), often with a red mottle and some quartz gravel. This soil grades into a lighter clay, sometimes with calcium carbonate segregations which then grades into weathered regolith. The profile depth is about 100 cm or more with variable depths of the surface horizons, generally 15 cm for the surface and 20 cm for the subsurface, occasionally deeper.

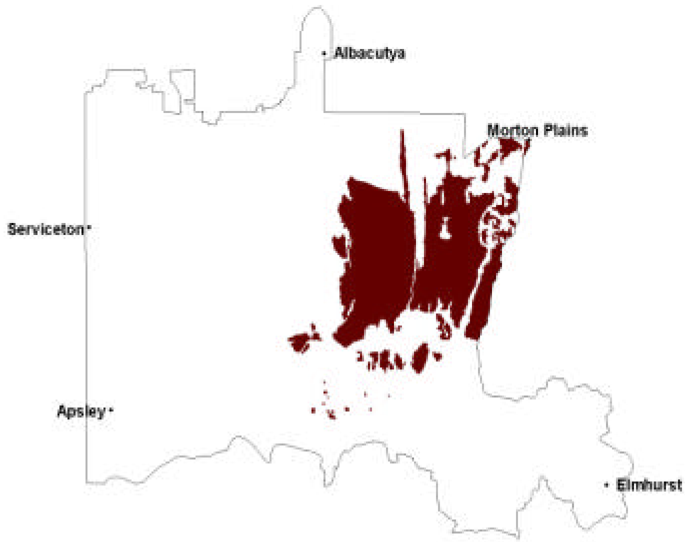
Notable features include:

- Texture contrast soil, seasonally wet in much of the unit, associated with a series of lakes and depressions, most of which are saline.
- Site drainage is very slow.
- Variable surface friability (generally sandy and soft, occasionally hardsetting).
- Occasional bleached subsurface soil.
- Mottled subsoil has restricted soil drainage, often strongly sodic at depth, highly dispersive and strong consistence (strength) when dry.
- Some better drained variants do occur in the unit.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| NA171 | Natimuk-Douglas valley | Playa | Eutrophic, Mottled-Subnatric, Brown Sodosol | Dy5.42 | T7224 - NATIMUK |
| NA141 | Natimuk-Douglas valley | Hillslope | Calcic, Mottled-Subnatric, Brown Sodosol | Dy3.43/ 5.43 | T7224 - NATIMUK |
| NA178 | Natimuk-Douglas valley | Crest | Haplic, Calcic, Red Kandosol | Gc1.2 | T7224 - NATIMUK |

## 34. Cracking clay soils/Clay plain with subdued ridges




These soils have developed on Quaternary unconsolidated material, generally of aeolian and lacustrine origin in the North West Dunefields and Plains, to the north of Horsham. They occupy plains and swales, and may occur in association with occasional vertic, sodic texture contrast soils. The Sodosols are associated with gilgai micro relief (Vertosol/Sodosol complex). The soil is alkaline throughout and calcareous.

The surface soil is usually a dark grey, light to medium clay. This is self-mulching, subplastic and has weak structure (coarse granular). There is a clear change to a dark grey (occasionally grey) heavy clay subsoil horizon. This is strongly structured with coarse to medium sized peds, occasionally slightly mottled and with few calcium carbonate segregations below the upper subsoil. This soil grades into a yellower heavy clay at depth. The profile depth is about 130 cm or more to the paler clay continuing below 2 m, with depth of the surface horizon generally about 10 cm.

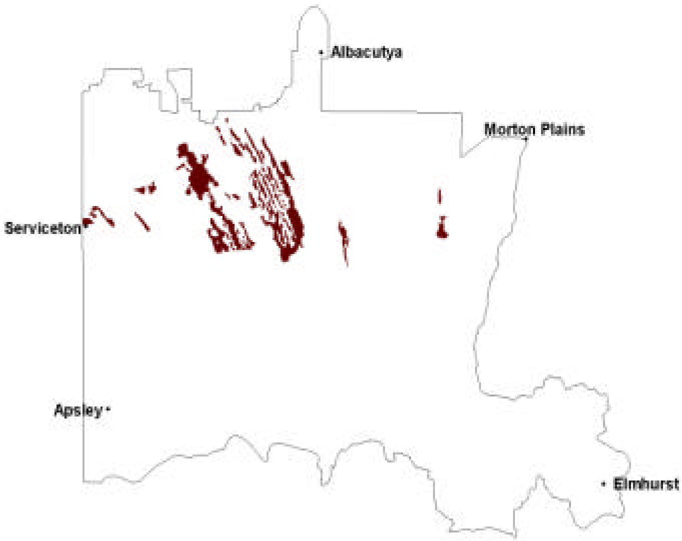
Notable features include:

- Cracking clay with highly self-mulching surface (high calcium content).
- Surface generally friable (self-mulching or pedal), strong consistence (strength) when dry.
- Very occasional bleached subsurface soil.
- Mottled or pale subsoil at depth has restricted soil drainage, often strongly sodic and likely to be dispersive.
- Occasional red or brown subsoil variants.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WIA6 | Kalkee plains | Summit surface | Epicalcareous-Endohypersodic, Self-Mulching, Grey Vertosol | Ug5.28 | T7125-KANIVA |
| WIA9 | Kalkee plains | Hillslope | Endocalcareous-Endohypersodic, Self-Mulching, Grey Vertosol | Ug5.25 | T7125-KANIVA |
| WIA5 | Kalkee plains | Plain | Endocalcareous-Endohypersodic, Self-Mulching, Grey Vertosol | Ug5.3 | T7125-KANIVA |

## 35. Sodic, red texture contrast soils/Ridges with sand and flats: Prominent ridge tops and oriented swales




These soils have developed on Quaternary unconsolidated material, generally of aeolian origin in the North West Dunefields and Plains, north of the Little Desert. They usually have neutral to alkaline surfaces and alkaline subsoils.

The surface soil is usually a dark brown sandy clay loam, which is weakly structured. It occasionally overlies a sporadically bleached subsurface horizon, occasionally capping the subsoil. There is a clear change to a reddish brown (occasionally yellowish red) medium clay subsoil horizon. This is strongly structured (coarse parting to medium sized peds) and sodic. This soil grades into a red, heavy sodic clay which is moderately structured. This becomes lighter in texture with many calcium carbonate soft segregations with depth. This grades into a lighter textured and paler (light yellowish brown) sandy clay which will grade into weathered regolith either unconsolidated or sandstone. The profile depth is about 100 cm or more (depending on topographic position) with variable depths of the surface horizons, generally 10 cm for the surface and 10 cm for the subsurface, occasionally deeper surface soil.

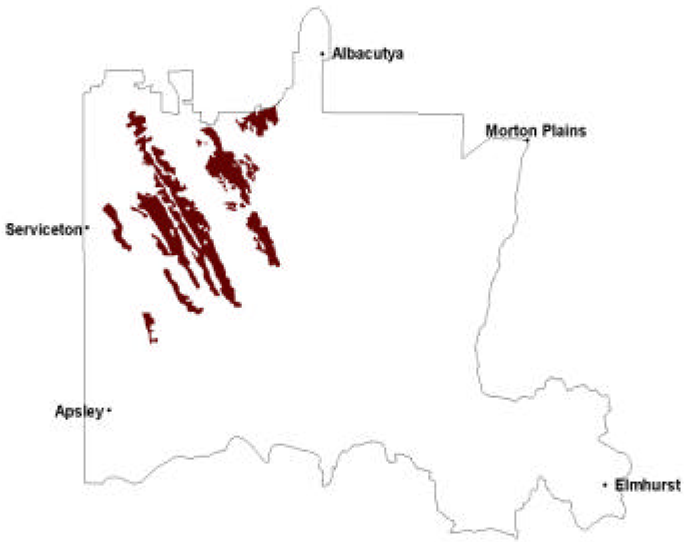
Notable features include:

- Texture contrast soil, variable surface friability (generally hardsetting).
- Strong consistence (strength) when dry, occasional sporadic bleached subsurface soil. Strong consistence contrast (strength) between shallow surface soil and sodic subsoil.
- Strongly sodic at depth, also high dispersion.
- Free (visible) calcium carbonate is common to dominant in subsoil.
- Mottling generally absent until transition to parent material.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| LS15 | Kiata rises | Plain | Hypercalcic, Hypernatric, Red Sodosol | Dr2.33 | T7225 - NHILL |
| LS8 | Broughton undulating plains | Dunecrest | Vertic, Mesonatric, Red Sodosol | Dr2.13 | T7125 - KANIVA |
| LS23 | Woorak clay plains | Plain | Hypercalcic, Subnatric, Red Sodosol | Dr4.33 | T7225 - NHILL |

## 36. Sodic, brown, yellow and grey texture contrast soils/Ridges with sand and flats: Prominent ridge tops and oriented swales




These soils have developed on Quaternary unconsolidated material, generally of aeolian origin in the North West Dunefields and Plains, north of the Little Desert. The soil has a slightly acidic surface, slightly alkaline upper subsoil and strongly alkaline below the upper subsoil.

The surface soil is usually a dark brown, sandy clay loam, which is apedal (sandy) to weakly structured. It occasionally overlies a bleached apedal subsurface horizon. There is a sharp to abrupt change to a yellowish brown, medium heavy clay subsoil horizon. This is moderately structured (coarse to medium sized peds), often with a red mottle and a few ferruginous concretions. This soil grades into a light brownish grey or yellowish brown, medium heavy clay with some to many calcium carbonate segregations. This then grades into a yellower heavy clay with slickensides and may lighten in texture with depth and be mottled where grading into weathered sandstone. The profile depth is about 100 cm or more with variable depths of the surface horizons, generally 5-15 cm for the surface and 10 cm for the subsurface.

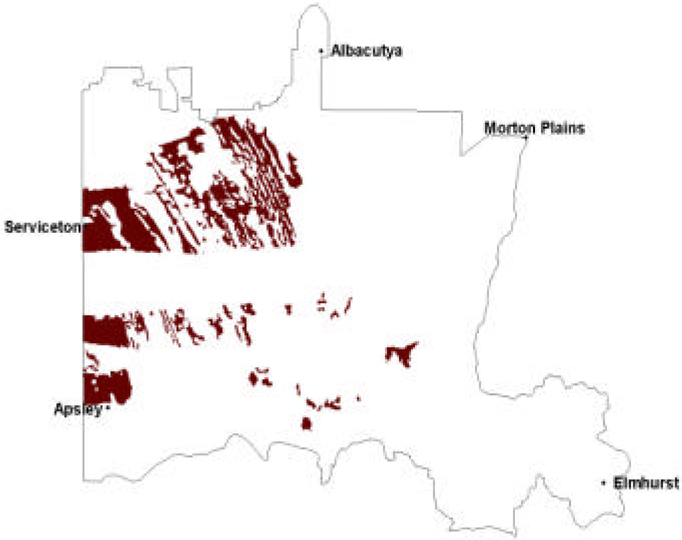
Notable features include:

- Texture contrast soil.
- Little surface friability (generally hardsetting).
- Strong consistence (strength) when dry.
- Occasional sporadic bleached subsurface soil.
- Strong consistence contrast (strength) between shallow surface soil and subsoil.
- Free (visible) calcium carbonate is common to dominant in subsoil.
- Mottling generally absent except where grading into parent material.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| LS2 or LS13 | Kiata rises | Hillslope | Vertic, Mottled-Subnatric, Brown Sodosol | Db2.13 | T7225 - NHILL |
| LS24 or LS6 | Lorquon undulating plains | Riseslope | Hypercalcic, Subnatric, Brown Sodosol | Dy2.13 | T7225 - NHILL |
| LS10 or LS22 | Diapur ridge | Hillslope | Calcic, Mottled-Mesonatric, Yellow Sodosol | Dy4.43 | T7225 - NHILL |

## 37. Grey and brown cracking clay soils/Ridges with sand and flats




These soils have developed on Quaternary unconsolidated material, generally of aeolian and lacustrian origin in the North West Dunefields and Plains, north and south of the Little Desert. This soil is alkaline and generally calcareous throughout.

The surface soil is usually a dark grey medium clay. This is strongly structured and self-mulching. There is a clear change to a grey (occasionally light grey), heavy clay subsoil horizon. This is strongly structured (with coarse sized peds), sodic and occasionally has very few ferromanganiferous concretions. This soil grades into a paler, light olive grey, medium heavy clay. This is strongly structured (with coarse sized peds), has slickensides and some to many calcium carbonate concretions. This soil grades into weathered regolith at depth. The profile depth is about 2 m or more with variable depth of the surface horizons, generally 5-10cm for the surface and 5-10 cm for the subsurface, where it exists.

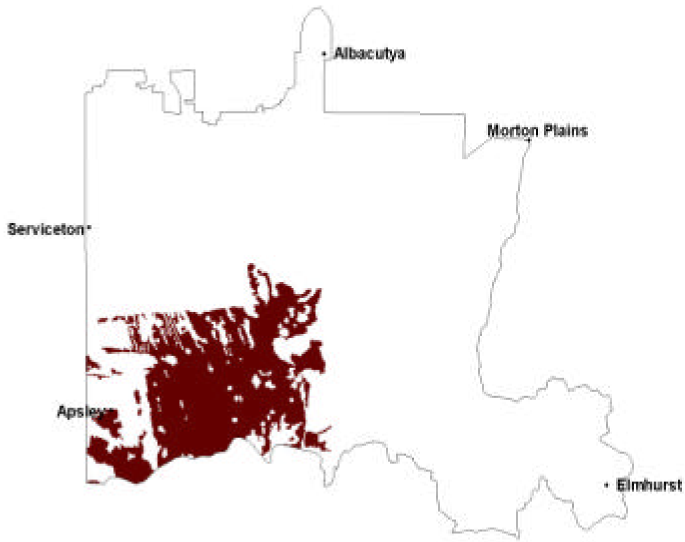
Notable features include:

- Cracking clay soil with self-mulching surface.
- Generally self-mulching and pedal surface condition.
- Strong consistence (strength) when dry.
- Very occasional sporadic bleached subsurface soil.
- Free (visible) calcium carbonate is common to abundant in subsoil.
- Mottling generally absent.
- There is a brown to red variant (subsoil colour).

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| LS3 | Woorak clay plains | Swale | Epicalcareous-Epihypersodic, Self-Mulching, Grey Vertosol | Ug5.24 | T7225 - NHILL |
| LSWW9 | Lillimur South clay plains | Plain | Epicalcareous-Endohypersodic, Self-Mulching, Grey Vertosol | Ug5.28 | T7125 - KANIVA |
| LSWW5 | Diapur ridge | Riseslope | Epicalcareous-Epihypersodic Self-Mulching, Brown Vertosol | Ug5.35 | T7125 - KANIVA |

## 38. Sodic brown, yellow and grey texture contrast soils/Ridges with sand and flats: Low remnant ridge tops with aeolian sands and oriented swales




These soils have developed on Quaternary unconsolidated material, generally of riverine, aeolian and lacustrine origin in the North West Dunefields and Plains, south of the Little Desert. The soil has a slightly acidic surface with a slightly acidic to slightly alkaline upper subsoil becoming strongly alkaline below. Variations may be influenced by climate variation.

The surface soil is usually a dark brown loamy sand which is apedal (massive or sandy) to weakly structured. It overlies a pale brown subsurface horizon which is bleached, apedal (massive or sandy) occasionally with ferruginous nodules (buckshot). There is a sharp/abrupt change to a brown to strong brown (occasionally yellow) medium heavy clay subsoil horizon. This is strongly structured (with coarse (columnar) to medium sized peds) and sodic. This overlies a pink, medium clay (fine sandy) horizon with a faint mottle, moderately structured (coarse sized peds), sodic and with variable free calcium carbonate. This soil grades into a reddish yellow mediuim clay, which is mottled before grading into weathered regolith (often sandstone). The profile depth is about 130 cm or more (at least 2 m) with variable depths of the surface horizons, generally 10 cm (5-20 cm) for the surface and 15 cm (5-30cm) for the subsurface, often deeper.

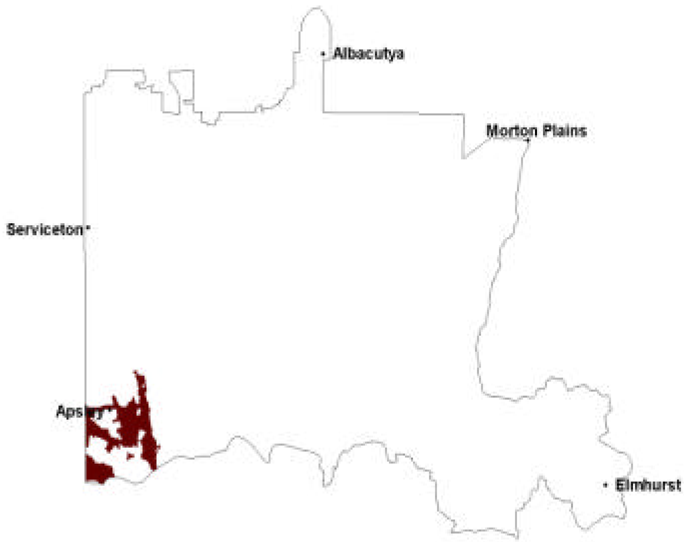
Notable features include:

- Texture contrast soil, subsoil is sodic.
- Variable surface condition (generally soft, occasionally hardsetting) with sandy surfaces.
- Strong consistence (strength) contrast between the lighter shallow surface and subsurface soil and heavy subsoil.
- Free (visible) calcium carbonate is common to dominant in mid subsoil.
- Subsoil mottling generally absent in drier environments, apart from transition to weathered regolith at depth.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| LSWW11 | Kybybolite plains | Hillslope | Hypercalcic, Mottled-Hypernatric, Brown Sodosol | Db4.43 | T7124-GOROKE |
| LSWW17 | Kowree undulating sand plains and ridges | Riseslope | Calcic, Mottled-Mesonatric, Yellow Sodosol | Dy5.43 | T7123-EDENHOPE |
| LSWW13 | Ullswater plains and rises | Riseslope | Calcic, Mottled-Mesonatric, Grey Sodosol | Dg4.43 | T7124-GOROKE |

## 39. Sodic red texture contrast soils/Ridges with sand and flats: Low remnant ridge tops with aeolian sands and oriented swales




These soils have developed on Quaternary unconsolidated material, generally of riverine, aeolian and lacustrine origin in the North West Dunefields and Plains, south of the Little Desert. This soil has a slightly acidic surface and subsurface over a neutral to alkaline subsoil.

The surface soil is usually a dark yellowish brown, sandy loam, which is weakly structured. It sharply overlies a red sandy loam subsurface horizon, which is bleached and weakly structured. There is a sharp/abrupt change to a yellowish red medium clay upper subsoil horizon. This is moderately structured (with medium sized peds) and sodic to strongly sodic. This soil grades into mottled deeper subsoil, and/or weathered parent material. The profile depth is about 100 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 20 cm for the subsurface.

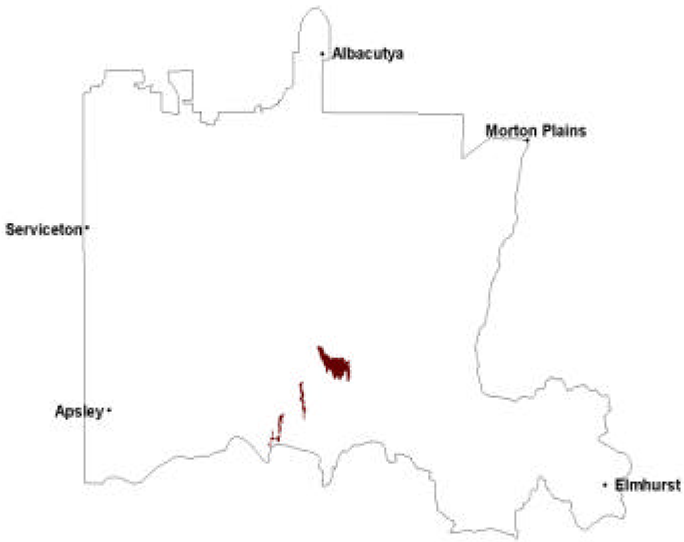
Notable features include:

- Texture contrast soil.
- Variable surface condition (generally hardsetting).
- Generally has a conspicuously bleached subsurface soil.
- Strong consistence (strength) of subsoil when dry.
- Strong consistence contrast (strength) between shallow surface soil and subsoil.
- The subsoil is sodic, often strongly sodic and dispersive.
- Free (visible) calcium carbonate may be present in subsoil.
- Mottling generally absent in upper subsoil.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| NA174 | Fairview plains | Hillcrest | Eutrophic, Mesonatric, Red Sodosol | Dy2.32 | T7224 - NATIMUK |

## 40. Sodic red and brown texture contrast soils/Ridges with sand and flats: Prominent ridges with eroded ferruginised spurs




These soils have developed on Quaternary unconsolidated material, generally of riverine, aeolian and lacustrine origin in the North West Dunefields and Plains, south of the Little Desert. This soil has a slightly acidic surface with a neutral to alkaline subsoil.

The surface soil is usually a dark brown loamy sand, which is apedal (sandy) to weakly structured and loose consistence. It generally abruptly overlies a brownish yellow loamy sand subsurface horizon. This is bleached and has some ferro-manganiferous concretions or indurated rock fragments. There is a sharp/abrupt change to a red, medium clay upper subsoil horizon. This is sodic, often with a brown mottle, strongly structured (with coarse to medium sized peds) and some ferro-manganiferous concretions or indurated rock fragments. This grades into more mottled and less structured subsoil which in turn grades into weathered material, often ferruginised (indurated) sandstone. The profile depth is about 80 cm or more with variable depths of the surface horizons, generally 10 cm for the surface and 5 cm for the subsurface, occasional deeper or absent on some crests.

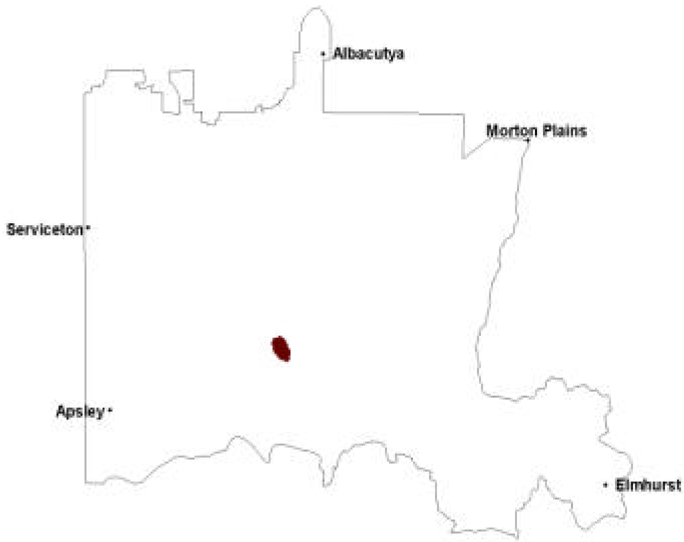
Notable features include:

- Texture contrast soil.
- Variable surface friability (generally soft) with sandy surfaces.
- Strong consistence (strength) contrast between weak surface and strong subsoil when dry.
- Generally has a bleached subsurface soil.
- Ferro-manganiferous concretions or ferruginised sandstone occur on soil surface and in the surface and subsurface soil in particular.
- The sodic subsoil may be strongly sodic and highly dispersible.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| HOR1 | Darragan rolling rises | Summit surface | Eutrophic, Mesonatric, Red Sodosol | Dr4.12 | T7324 - HORSHAM |
| HOR2 | Darragan rolling rises | Summit surface | Eutrophic, Mesonatric, Red Sodosol | Dr5.42 | T7324 - HORSHAM |

## 41. Shallow and sandy soils, sodic brown texture contrast soils/Hills and low hills




These soils have developed on Palaeozoic sediments, generally of Grampians sandstone making up Mount Arapiles, outlying in the North West Dunefields and Plains, south of the Little Desert. Soils are either Rudosols, sandy soils such as Tenosols or heavier soils such as Sodosols on the footslopes. The soils are acidic in higher positions but may be alkaline in lower positions (accumulation zones).

The surface soil is usually a dark greyish brown loamy sand which is apedal to weakly structured. This sharply overlies a yellowish brown sandy clay loam with an occasional bleached subsurface horizon in between. There is a clear change to a brown sandy clay loam to sandy clay upper subsoil horison. This is mottled, weakly structured (coarse to medium sized peds) with some quartz or rock fragments. This soil grades into lighter textured weathered material (sandstone). The profile depth is about 60 cm, less or more depending on topographic position with variable depths of the surface horizons, generally 5 cm for the surface, occasionally more.

Notable features include:

- Gradational and texture contrast soils.
- Variable surface condition (generally soft, occasionally hardsetting) with sandy surfaces.
- Occasional sporadic or conspicuously bleached subsurface soil.
- Strong consistence (strength) of heavier subsoil when dry.
- Texture contrast may not be spatially consistent depending on topographic position and rock formation.
- The heavier soils may be mottled, indicating restricted drainage and often sodic.

**Soil sites**

| Site code | Soil-landform unit | Component | ASC | FK | 1:100 000 mapsheet |
|---|---|---|---|---|---|
| WLRA54 | Arapiles steep hills | Hillslope | Bleached-Leptic Tenosol | Gn1.84/ Uc2.21 | T7324 - HORSHAM |
| NA172 | Arapiles steep hills | Hillslope | Eutrophic, Mesonatric, Brown Sodosol | Dr3.43 | T7224 - NATIMUK |

# 5 Land conservation and susceptibility

## 5.1 Land susceptibility

The terms hazard and susceptibility are often used interchangeably, causing much confusion. Susceptibility of land to a specific deterioration process is defined here as a constant inherent feature, but the hazard changes depending upon the level of management and the type of land use.

Soil erosion and sedimentation is considered to be a major problem and can reduce the productivity of agricultural land. Sediment is the greatest pollutant of the world's surface waters as it degrades water quality and may carry adsorbed polluting chemicals (Robinson 1971). Furthermore most soils have very slow rates of formation and should be considered as a non-renewable resource thus the management of these soils is a very important consideration. It is therefore prudent to assess the risk, or susceptibility, of land to various forms of degradation.

**Factors and processes**

In this report seven land degradation susceptibility processes were identified and studied. These are listed as follows:

- gully and tunnel erosion
- sheet and rill erosion
- wind erosion
- soil structure decline (compaction)
- soil sodicity (topsoil and subsoil)
- soil pH (topsoil and subsoil).

These processes have been investigated in previous studies. Previous land studies have used a suite of methods and approaches to define criteria and outputs representative of land degradation susceptibility across study areas. After evaluating existing methodologies with questionable output qualities, it was recommended to undertake an expert decision making approach for these processes. Experts with knowledge on catchment processes and limitations, collaborated in a suite of conferences and major meetings to identify limitations and inherent susceptibilities of the land to further degradation.

The main soil-landform characteristics influencing the susceptibility of land to decline included soil chemical and physical properties, topographic indicators (slope, aspect etc.), geology, geomorphological processes and climate. Vegetation, land use and historic land management practices weren't considered in this approach. The inherent susceptibility to land degradation (ha and %), soil sodicity and soil pH for land in the WCMA region is presented in Table 5–7.

Table 5 Inherent susceptibility to land degradation (ha and %) for land in the WCMA region

| Hazard | High and Very High | | Moderate | | Low and Very Low | |
|---|---|---|---|---|---|---|
| | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| Gully and tunnel erosion | 132443 | 5.7 | 1076613 | 46.5 | 1107970 | 47.8 |
| Sheet and rill erosion | 63401 | 2.7 | 985185 | 42.5 | 1268422 | 54.8 |
| Wind erosion | 1001457 | 43.2 | 1098882 | 47.4 | 216668 | 9.4 |
| Soil structure decline (compaction) | 436212 | 18.8 | 770353 | 33.2 | 1110443 | 48.0 |

Table 6 Soil sodicity (ha and %) for land in the WCMA region

| Sodicity | Very strongly sodic (ESP > 25 | | Strongly sodic (ESP 15–25) | | Sodic (ESP 6–15) | | Non sodic | |
|---|---|---|---|---|---|---|---|---|
| | (ha) | (%) | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| Topsoil | 117686 | 5.1 | 0 | 0 | 576971 | 24.9 | 1622371 | 70.0 |
| Subsoil | 846019 | 36.5 | 477772 | 20.6 | 660388 | 28.5 | 332830 | 14.4 |

Table 7 Soil pH (ha and %) for land in the WCMA region

| Soil pH | Acid (pH < 5.5) | | Neutral (pH 5.5–8.0) | | Alkaline (pH >8.0) | |
|---|---|---|---|---|---|---|
| | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| Topsoil | 89750 | 3.9 | 1551669 | 67.0 | 675590 | 29.1 |
| Subsoil | 1994 | 0.1 | 987044 | 42.6 | 1327971 | 57.3 |

**Gully and tunnel erosion**

The susceptibility of land to tunnelling and gully erosion depends on a number of interrelated factors. These are principally rainfall intensity, vegetation cover, rooting depth, microrelief, slope, position in landscape, contributing upslope area, soil permeability, soil depth, soil cohesion and dispersibility. As the volume of overland flow increases and becomes channelised, the erosive power increases and resistance of the soil aggregates and particles to detachment becomes critical. The size and weight of the soil particles and their cohesion, or the tendency to slake or disperse will determine the resistance.

Gully and tunnel erosion is potentially a major degradation threat to water quality and biodiversity. Nearly 132 000 hectares of the catchment has a high inherent susceptibility to gully and tunnel erosion. The areas of highest potential include the Cambro-Ordovician sediments in the Western Uplands, but gully and tunnel erosion is also common on granitic parent material across the uplands. The Pyrenees Range is extremely prone to tunnel and gully erosion where cleared (e.g. Joel South, Mapunit). When gradational soils and stony loams on crests and upper slopes are cleared of the native deep-rooted vegetation, some rain percolates through the soil profile to the watertable, but some becomes overland flow with the potential to sheet erode the sloping land and scour out drainage depressions.

The presence of gullies and tunnels adversely affects productivity in a number of ways. As well as the land directly lost from production, the soil adjacent to the gully or tunnel is excessively drained thus reducing the vigour and number of plant species able to survive.

**Sheet and rill erosion**

The susceptibility of land to sheet and rill erosion is governed largely by the topsoil texture, slope of the land and length of slope. Other factors include hydrophobicity, percentage stone cover, tendency for aggregates to slake and disperse, size and weight of surface particles or aggregates, and the probability of intense summer rainfalls.

Soil loss from sheet and rill erosion is difficult to assess because of variability in soil loss within an area, and the problem of measuring something that is no longer there. Sheet and rill erosion greatly reduces productivity, particularly in the case of texture contrast soils. The topsoil or A horizon is where most nutrients, organic matter, seeds and macroporosity so desirable for a seedbed exists. If this is stripped away through soil loss the fertility of the soil is lost and productivity reduced.

Nearly 45% of the region has a moderate inherent susceptibility to degradation by sheet and rill erosion. Lanscapes most prone to degradation include the Grampians Ranges, Pyrenees Range, and the sediments and granitic slopes of the Western Uplands.

### Wind erosion

Wind erosion is the loss of soil particles by wind. It occurs when the lift forces of the wind exceed the gravity and cohesion of the soil grains at the surface.

Susceptibility of land to wind erosion is determined by taking into account the inherent features of the soil, the climate and position in landscape. The erodibility of the topsoil is a major factor, but structure, texture, stoniness and organic matter are all significant. Land use and management may have a major influence on the degree of deterioration, particularly if dry soils are exposed when erosive winds are likely to occur. Wind erosion is likely to reduce the organic matter and nutrients available in the topsoil, while the reduction in topsoil depth also leads to reduced water infiltration causing increased runoff and a fall in productivity.

Over 1 001 457 ha (43.2%) of the region is considered to have a high inherent susceptibility to wind erosion. The loose sandy topsoils of the Little and Big deserts, the sandy dunes and ridge crests in the north of the region, and the granitic slopes of the Midlands are highly susceptible to wind erosion. The basalt plains with fine sandy loam topsoils, the well structured self-mulching soils of the Kalkee Plains, and the gradational and uniform soils of the Western Uplands have moderate to low susceptibilities.

### Soil-structure decline

Soil structure decline is the terminology used to refer to changes in the stability of soil aggregates and changes in arrangement of spaces (porosity) within soil material that result in conditions that are less favourable to plant growth. Changes in aggregate stability occur through excess tillage (pulverising when dry, dispersing when wet) and through prolonged (over years) cropping or grazing with resulting reduction of soil organic matter. Changes in porosity may result from compressing and churning moist or wet soil by wheels or hooves causing compaction and pugging. The primary affects are on soil hydrology, aeration, soil strength and root development. Soil structure decline can also increase the incidence of waterlogging and make the soil more susceptible to erosion by wind or water.

Soil texture, organic matter, mineralogy, climate, topography, and vegetation all affect the degree to which soil structure is susceptible to decline.

Potentially the greatest land degradation issue across the WCMA region, soil-structure decline has a large area highly likely to be inherently susceptible to degradation. Over 436 000 ha or 18.8% has a high rating. Landscapes thought most vulnerable include the sedimentary slopes and plains of the Western Uplands where hardsetting soil surfaces are common, and the massive cracking clay soils and sodic texture contrast soils of the North West Dunefields and Plains.

### Soil sodicity

Soil sodicity refers to the measure of exchangeable sodium ($Na^+$) ions in soil relative to other exchangeable cations including calcium ($Ca^{2+}$), potassium ($K^+$), aluminium ($Al^{3+}$) and magnesium ($Mg^{2+}$) with sodic soils having high levels of sodium. Sodium causes soils to disperse where aggregations of clay separate into individual platelets, leading to soil structure decline. This dispersion often results in reduced hydraulic conductivity and reduced percolation of water through the soil profile. As well, surface sealing can occur also contributing to poor infiltration rates. Sodic subsoils are therefore extremely prone to gully and tunnel erosion where subsoils are exposed.

Sodicity can have significant effects on agricultural production. Management problems associated with sodic subsoils are many, including poor trafficability, soil structure decline (compaction) and poor aeration (waterlogging) for example. Surface sealing also forms a suite of physical constraints to plant growth. Fertility constraints of sodic soils are often conveyed through secondary affects including reduced nitrogen availability, calcium deficiency and low organic matter levels. Engineering and erosion problems are many including piping (tunnel erosion) that often impact on bank and earth structures as well as road pavements.

Soil sodicity (topsoil) is thought to affect 30% of the WCMA region soils, while sodic subsoil affect nearly 2 000 000 ha (85.6%) across the catchment. This greatly impacts upon not only soil compaction and waterlogging, but also gully and tunnel erosion as well. Areas included are the plains and dunes in the north of the catchment (often calcareous and sodic, mesonatric or hypernatric); the swales and rises west of the Douglas-Natimuk valley and Lowan Salt Valley; the Cainozoic rises and plains within the lower reaches of the upper Wimmera area; and the hardsetting plains associated with prior streams and modern stream channels in the east of the catchment.

### Soil pH

Soil acidity and alkalinity present widespread limitations to plant and animal production across the WCMA region. Soil pH reflects the concentration of $H^+$ ions against $OH^-$ ions with values less than 7.0 considered ‘acidic’ and values above 7.0 ‘alkaline’. A soil pH of 7.0 ± 0.5 is loosely referred to as ‘neutral’.

Soil acidification effects are primarily related to an increase of soluble and exchangeable aluminium leading to toxicities in sensitive plants, and a decrease in soluble and exchangeable calcium and magnesium leading to deficiencies. This alumium toxicity has a direct effect on plant metabolism where roots become shortened and thickened. Alkaline soils contain significant concentrations of calcareous, dolomitic or sodic carbonate. This carbonate causes alkaline conditions with the most common effect being chlorosis of leaves of sensitive plants. Chlorosis is reflected by the plants inability to process and utilise iron and managanese, therefore impacting on overall plant metabolic activity and efficiency. Phosphatic deficiencies are also common on calcareous soil.

Over 90 000 ha (4%) of the region is considered to have a high inherent susceptibility to acid soils. The higher rainfall areas of the ranges (Grampians, Pyrenees and Langi Ghiran) typically have moderately acidic surfaces that trend towards neutral in the subsoil. Plains south of the Little Desert (e.g. Ullswater, Kowree, Horsham South) also show distinctly lower topsoil pH values than those north of the desert. This has been attributed to slightly higher rainfall and land use differences as a result. Topsoil pH on the Kalkee plains are near neutral along with the rises and swales further west, however further north (e.g. Jeparit, Peppers Plains) values are often alkaline with some surface values near a pH of 10. Subsoils here are still alkaline but may become neutral at depth (>1.5 m).

# Appendix A Criteria used in land degradation analysis

### Soil compaction

Soil types were assessed for all attributes and a mean value assigned as the rating for soil compaction. Extreme values were also considered in the analysis and their potential to be the major limiting factor. Dry consistence of surface soil, organic carbon and surface condition were used as part of the analysis. Note that page references refer to the *Australian Soil and Land Survey Field Handbook* (McDonald et al. 1990) or *Soils - their properties and management* (Charman & Murphy 1991).

*Dry consistence of surface soil (p. 138 - McDonald et al. 1990)*

| | Rating | Break force | Class |
|---|---|---|---|
| 1 | Low | Loose, very weak | < 2 |
| 2 | Moderate | Moderately weak | 2 |
| 3 | High | Firm, very firm, strong, rigid | > 2 |

*Organic carbon (p. 206 - Charman & Murphy 1991)*

| | Rating | % Carbon |
|---|---|---|
| 1 | Low | > 3 |
| 2 | Moderate | 1.5–3 |
| 3 | High | < 1.5 |

*Surface condition (p. 141 - McDonald et a.l 1990)*

| | Rating | Condition |
|---|---|---|
| 1 | Low | Self-mulching, loose |
| 2 | Moderate | Soft, firm (relative to Org C) |
| 3 | High | Hardsetting, surface crust, surface flake, cracking, fir (relative to Org C) |

***Overall rating for soil compaction***

| | Rating |
|---|---|
| 1 | Low |
| 2 | Moderate |
| 3 | High |

### Wind erosion

The susceptibility of land to wind erosion is a function of soil erodibility, the probability of erosive winds when the soil is dry and the exposure of the land component to wind (Lorimer 1985).

***Rating for wind erosion***

| | Soil type | Rating |
|---|---|---|
| **1** | Surface soil has a strong blocky structure (aggregates > 0.8 mm), or is apedal and cohesive or has a dense layer of stones, rock or gravel | Very low |
| | Surface soil has strong fine structure (aggregates < 0.8 mm) | Moderate |
| | Surface soil has a weak-moderate structure or is apedal and loose | Go to 2 |
| **2** | Surface soils with organic matter > 20% | High |
| | Surface soils with organic matter 7-20% | Moderate |
| | Surface soils with organic matter < 7% | Go to 3 |
| **3** | Surface soils with the following textures: | |
| | Fine-medium sands | Very high |
| | Loamy sands | High |
| | Sandy loams, silty loams | High |
| | Loams, coarse sands | Moderate |
| | Clay loams | Low |
| | Clays | Very low |

### Sheet and rill erosion

The following table has been adapted from Elliott and Leys (1991). The erodibility index for a range of soil properties closely relates to the susceptibility of soils to erosion by water, and in the tables below, the same soil properties have been used (texture, structure grade, topsoil depth and dispersibility (Emerson aggregate test)) which are then related to slope to determine a rating for susceptibility. The final rating for susceptibility to sheet/rill erosion is read from the erodibility of the topsoil and the slope of the area.

*Erodibility index*

| Soil parameters | | | Soil dispersibility | | |
|---|---|---|---|---|---|
| **Texture group (A1)** | **Structure grade (A1)** | **Horizon depth (A1 + A2)** | **Very Low - Low** E3(1), E3(2), E4,E5, E6, E7, E8 | **Medium - High** E3(3), E3(4), E2 | **Very High** E1 |
| Sand | apedal | < 0.2 m | M | | |
| | | 0.2-0.4 m | L | | |
| | | > 0.4 m | L | | |
| Sandy loam | apedal | < 0.2 m | M | H | |
| | | 0.2-0.4 m | L | M | |
| | | > 0.4 m | L | | |
| | weakly pedal | < 0.2 m | H | E | |
| | | 0.2-0.4 m | M | V | |
| | | > 0.4 m | M | | |
| Loam | apedal | < 0.2 m | M | H | |
| | | 0.2-0.4 m | L | M | |
| | | > 0.4 m | L | | |
| | weakly pedal | < 0.2 m | H | E | |
| | | 0.2-0.4 m | M | V | |
| | | > 0.4 m | M | | |
| | peds evident | < 0.2 m | H | E | |
| | | 0.2-0.4 m | H | | |
| | | > 0.4 m | H | | |
| Clay loam | apedal | < 0.2 m | M | H | |
| | | 0.2-0.4 m | L | M | |
| | | > 0.4 m | L | | |
| | weakly pedal | < 0.2 m | H | E | |
| | | 0.2-0.4 m | M | V | |
| | | > 0.4 m | M | | |
| | peds evident | < 0.2 m | H | E | |
| | | 0.2-0.4 m | H | E | |
| | | > 0.4 m | M | | |
| Light clay | weakly pedal | < 0.2 m | H | E | E |
| | | 0.2-0.4 m | M | V | E |
| | | > 0.4 m | M | V | E |
| | peds evident | < 0.2 m | M | V | E |
| | | 0.2-0.4 m | M | H | E |
| | | > 0.4 m | M | H | E |
| | highly pedal | < 0.2 m | H | E | |
| | | 0.2-0.4 m | M | V | |
| | | > 0.4 m | M | V | |

L - Low M - Moderate H - High V - Very high E - Extreme

| **Soil parameters** | | | **Soil dispersibility** | | |
|---|---|---|---|---|---|
| **Texture group (A1)** | **Structure Grade (A1)** | **Horizon depth (A1 + A2)** | **Very Low - Low** E3(1), E3(2), E4,E5, E6, E7, E8 | **Medium - High** E3(3), E3(4), E2 | **Very High** E1 |
| Medium to heavy clay | weakly pedal | < 0.2 m | M | H | E |
| | | 0.2-0.4 m | M | H | V |
| | | > 0.4 m | M | H | V |
| | peds evident | < 0.2 m | H | E | E |
| | | 0.2-0.4 m | M | V | E |
| | | > 0.4 m | M | V | E |
| | highly pedal | < 0.2 m | H | E | E |
| | | 0.2-0.4 m | M | V | E |
| | | > 0.4 m | M | V | E |

***Susceptibility of soil to sheet and rill erosion (using topsoil erodibility from above)***

| **Slope %** | **Topsoil erodibility (from table above)** | | | | |
|---|---|---|---|---|---|
| | **Low** | **Moderate** | **High** | **Very high** | **Extreme** |
| < 1 % | Very low | Very low | Low | Low | Moderate |
| 1-3 % | Very low | Low | Moderate | Moderate | High |
| 4-10% | Low | Moderate | Moderate | High | Very high |
| 11-32% | Moderate | Moderate | High | Very high | Very high |
| > 32% | Moderate | High | Very high | Very high | Very high |

*Note: Topsoil erodibility is determined from the texture, structure, depth and dispersibility of the topsoil. The susceptibility of the topsoil to sheet and rill erosion relates to the combined effect of slope and topsoil erodibility.

## Gully and tunnel erosion

No single factor can adequately represent the susceptibility of an area to the gully erosion process. A number of factors are involved and each should be scored independently and then the sum of the scores can be related back to a 5-class rating.

It should be noted that plains or landforms of significant area with low slopes and little upland surface water contribution (e.g. level plains, vast floodplains) have been rated in depth to rock/hardpan as low (2) or very low (1) for this attribute. These deep soils are relatively unlikely to experience flow gradients that will significantly contribute towards gully and tunnel erosion susceptibility.

***Susceptibility to gully and tunnel erosion***

| Criteria | Description | Score |
|---|---|---|
| Slope | < 1% | 1 |
| | 1-3% | 2 |
| | 4-10% | 3 |
| | 11-32% | 4 |
| | > 32% | 5 |
| Subsoil dispersibility | E1 | 5 |
| | E2, E3(3), E3(4) | 4 |
| | E3(1), E3(2) | 3 |
| | E4, E5 | 2 |
| | E6, E7, E8 | 1 |
| Depth to rock/hardpan | 0-0.5 m | 1 |
| | 0.6-1.0 m | 2 |
| | 1.1-1.5 m | 3 |
| | 1.6-2.0 m | 4 |
| | > 2.0m | 5 |
| Subsoil structure | Apedal, massive | 1 |
| | Weak | |
| | fine < 2 mm | 3 |
| | moderate 2-10 mm | 2 |
| | coarse > 10 mm | 1 |
| | Moderate | |
| | fine < 2 mm | 4 |
| | moderate 2-10 mm | 3 |
| | coarse > 10 mm | 2 |
| | Strong | |
| | fine < 2 mm | 5 |
| | moderate 2-10 mm | 3 |
| | coarse > 10 mm | 1 |
| | Apedal, single grained | 5 |
| Lithology of substrate | Basalt | 1 |
| | Volcanic | 2 |
| | Rhyodacite | 2 |
| | Granite | 4 |
| | Alluvium | 3 |
| | Colluvium | 5 |
| | Tillite | 4 |
| | Ordovician sandstone/mudstone | 5 |
| | Silurian sandstone/mudstone | 4 |

| Rating for susceptibility to gully erosion: | Class | Total score |
|---|---|---|
| | 1. Very low | 6-10 |
| | 2. Low | 11-13 |
| | 3. Moderate | 14-16 |
| | 4. High | 17-20 |
| | 5. Very high | 21-25 |

### Soil sodicity (topsoil or subsoil)

Sodicity is a measure of the exchangeable sodium in relation to other exchangeable cations. It is expressed as the Exchangeable Sodium Percentage (see ESP). A sodic soil contains sufficient exchangeable sodium to interfere with the growth of plants, including crops. A soil with an ESP greater than 6 is generally regarded as being a sodic soil in Australia (Northcote and Skene 1972). ESP levels are further classified in the *Australian Soil Classification* (Isbell 1996).

The sodicity level of a soil can be quantitatively tested in the laboratory by determining the proportion of sodium (Na%) present in the Cation Exchange Capacity (see CEC). That is:

$$\text{ESP (or Na\%)} = \frac{\text{sodium}}{\text{calcium} + \text{magnesium} + \text{sodium} + \text{potassium}} \times 100$$

This provides an Exchangeable Sodium Percentage value which determines the sodicity of the soil.

If the ESP value is:

| ESP value | Description | Subsoil description |
|---|---|---|
| <6 | Non-sodic | Non-sodic |
| 6–15 | Sodic | Subnatric |
| 15–25 | Strongly sodic | Mesonatric |
| >25 | Very strongly sodic | Hypernatric |

### Soil pH (topsoil or subsoil)

Soil pH provides a measure of soil acidity and soil alkalinity on a scale of 0 (extremely acidic) to 14 (extremely alkaline), with a pH of 7 being neutral. It gives an indication of the availability of plant nutrients and relates to the growth requirements of particular crops. Acid soils are usually deficient in necessary nutrients e.g. calcium and magnesium, while alkaline soils are often high in boron, affecting plant production.

The criteria used for soil $pH_{(water)}$ for topsoil and subsoil is:

- $pH_{(water)} < 5.5$ = acidic
- $pH_{(water)} > 5.5$ and $< 8.0$ = neutral
- $pH_{(water)} > 8.0$ = alkaline

# Appendix B Mapsheet reliability

| Mapsheet | Data used in mapping | Map notes | Mapping reliability (polygonal) | Soil attribution reliability | Combined data confidence level |
|---|---|---|---|---|---|
| Natimuk | Radiometrics; aerial photos used in West Wimmera study (Baxter, Williamson & Brown 1996) & Dept of Ag. study (Maher & Martin 1990), public land has been excised in W.W. Limited sites on public land, especially Little Desert. Mapping based on degree of landscape disaggregation (e.g. Lowland/lake complexes). Radiometrics doesn't show relief or particularly buried Parilla relict beach ridges (covered by Lowan Sand). Sites include W. Wimmera and WLRA sites. | Radiometrics have been extremely useful in revision of plains (gentle and undulating). Many similarities between Maher & Martin (1990)and Baxter, Williamson & Brown (1996). The Ko/Go units can be a little mixed and reflected in radiometric signature. The Douglas Depression and Mount Arapilies have had linework altered using radiometrics for internal boundaries. Some of the hydrology units (West Wimmera wetlands) defined by Baxter, Williamson & Brown (1996) haven't been pulled out, but could still with further refinement Detail by Muller & Hocking(2002b) hasn't been used heavily due to scale, but also to match linework between this sheet and neighbouring Horsham. | 4 | 3 | 7 |
| Kaniva & Wallowa | Radiometrics and aerial photos were used in the West Wimmera study (Baxter, Williamson & Brown 1996) & Dept of Ag. study (Maher & Martin 1990) where public land has been excised across the West Wimmera Shire. Mapping based on degree of landscape disaggregation (e.g. Lowland/lake complexes). Radiometrics doesn't show relief or particularly buried Parilla relict beach ridges (covered by Lowan Sand). Sites include W. Wimmera, NWRS sites and WLRA sites. The Broughton plains area has been defined due to sodic topsoils, small light patches in Big Desert = clay. | Linework from Baxter, Williamson & Brown (1996) has been preserved through out the Telopea Downs area and most to the south. A rise west of Lillimur has been incorporated into a unit of wider expanse (radiometric signature alike). A boundary between Pg5 and Pg7 hasn't been incorporated, but may be later. Linework of the Lowan study (Williamson 1997) is complementary with the Baxter, Williamson & Brown (1996) mapping and radiometrics. There have been minor alterations to linework, however, most has been kept. Linework should link in with Goroke and Nhill. | 3.5 | 3.5 | 7 |

| Mapsheet | Data used in mapping | Map notes | Mapping reliability (polygonal) | Soil attribution reliability | Combined data confidence level |
|---|---|---|---|---|---|
| Nhill & Albacutya | Radiometrics, photos Shire of Lowan, extrapolation east of shire. Smaller units in Shire and how they were defined is unclear. Soil differences, check Propodollah area (large Parilla area). Boundary with Wimmera River - Woorinen goes to river in north. Lake systems west of river are gypaceous (part of Wimmera trench?). Boundary of sand with calcareous material, need N/S boundary (from E to W). Little investigation of Public land (Little Desert). Sites include Lowan, WLRA sites and NWRS. | Lowan (Williamson 1997)linework API correlated very well with radiometrics. The distinction between the grey clay plains and gently undulating plain was difficult to determine, especially the boundary. The main Parilla ridge running through the centre used Lowan boundary, however between Nhill and Propodollah there may be another unit (radiometric signature not characteristic of gently undulating plain). The Wimmera Trench has been subdivided using radiometrics and swamp density as a guide. Prominent sand rises here have been pulled out with major swamps/waterbodies. More gently undulating rises have been pulled out in the N-E using radiometrics. Muller & Hocking's (2002a) coarse and rise/lower sand rises are equivalent to the gently undulating rises of Parilla Sand. | 4 | 2 | 6 |
| Goroke | Radiometrics; aerial photos used in West Wimmera study (Baxter, Williamson & Brown 1996) & Dept of Ag. study (Maher & Martin 1990), public land includes Little Little Desert (south of Little Desert). N-S trending ridges and valleys (lake systems) are defined more through D of Ag and less than W Wimmera (Q. Is this Shepparton Formation or still some Woorinen?). Stranded beach ridges subdued and covered by Lowan Sand (not visible in radiometrics). Some boundaries due to minor landform changes in gently undulating to undulating landscape. Sites include W. Wimmera, NWRS sites, Topcrop sites and WLRA sites. | Abundance of existing mapping -difficulty arose in determining level of detail required. Main issue was Baxter, Williamson & Brown's Pg10 v. Pg11 v. Pg12. South of the Little Desert are the main issues. Detail hasn't been extracted, but can be if required. Radiometrics has helped refine boundaries of plains units. | 4.5 | 3.5 | 8 |

| Mapsheet | Data used in mapping | Map notes | Mapping reliability (polygonal) | Soil attribution reliability | Combined data confidence level |
|---|---|---|---|---|---|
| Rupanyup | Radiometrics and aerial photos 1:80 000 used in derivation of linework for Badawy (1984) and White et al. (1985). Landscape complex due to overlap between plains and topographically significant in upper Wimmera. Sites are from NWRS survey (Martin & Imhof 1992) as well as reference sites by Badawy (1984). TopCrop sites also exist. | Mapping - radiometrics extremely useful in highlighting changes between plains and rises/low hills/hills to the south. Prior stream and floodplain complex is well defined, however boundaries within difficult to define. Sand veneers from Grampians-sourced sediments prominent in the south-west. Tertiary rises haven't been further defined between Stawell and Glenorchy (might be later). Definition within the plain (Wimmera River floodplain) hasn't been pulled out, however at finer scales would be (e.g. Terraces, etc.). Badawy’s linework on the cracking plains has been preserved. The White et al. (1985) linework is detailed in the region and has been preserved for topographically significant landforms. | 3 | 3 | 6 |
| Balmoral | Studies include West Wimmera (Baxter, Williamson & Brown 1996) and Kowree (Blackburn & Gibbons 1956). Landforms from West Wimmera align with Natimuk sheet. Public land has been included in revision. Subdued landscape, differences between texture contrast soils and heavy clays difficult to discern on radiometrics. Lake system complexes common, degree of disaggregation. Links to Tertiary surface in south and east not well understood. Sites include West Wimmera, WLRA. West Wimmera inspection sites need following up. | Linework from Baxter, Williamson & Brown (1996) has been used extensively, however, many lines have received slight shifts in accordance with radiometrics. This has been justified as all of these units are plains. Units with a strong hydrology influence have been preserved except in the N-W corner. New linework has been generated for the Brookersly to Toolondo region using radiometrics as a basis. Review against Kowree required. In the east, detail of the Rocklands-Upper Wimmera study (White et al. 1985) has been difficult to preserve. More work required here perhaps. | 3 | 3 | 6 |
| Donald | Photos - Dept of Ag. prior to 1983, Wimmera Plains includes prior stream complexes, cracking clay plains (self mulching Kalkee Clay and massive to epipedal Murtoa Clay). Radiometrics inconsistent creating issues in centre to east of sheet. Limited field work from Eastern Wimmera. Sites include Badawy (1984) Eastern Wimmera reference sites, WLRA sites. No soil pit data exists. | Mapping included prominent radiometric signatures that were defined within map previously defined by Badawy (1984). Linework of East Wimmera correlated reasonably well with radiometrics, however, given little relief over the region, API mightn't have provided detail at scale. Mapping will mosaic in with surrounding tiles well. Boundary between Mallee soils and Wimmera Plains are well defined. | 2.5 | 3 | 5.5 |

| Mapsheet | Data used in mapping | Map notes | Mapping reliability (polygonal) | Soil attribution reliability | Combined data confidence level |
|---|---|---|---|---|---|
| Warracknabeal | Radiometrics, no API existing for this sheet. Sites include Kalkee sites (Badawy 1977b), NWRS sites, TopCrop sites as well as significant E-W trending transects undertaken as part of the LRA project. | Mapping was very dependent upon radiometrics with no existing mapping. Landforms defined by Muller & Hocking (2002a) show good correlation with radiometrics. Ridges (highly likely Parilla Sand) are prominent landforms in a NW-SE trend throughout the region. The Yarriambiack is a prominent drainage network within the plain as well as the Wimmera River in the west. The boundary between the Mallee and Wimmera Plains hasn't been defined and may be a transition. Further mapping will be required and API would be extremely beneficial. With regard to mapping this area has the lowest confidence. | 2 | 2 | 4 |
| Edenhope | Overlapping surveys include West Wimmera (Baxter, Williamson & Brown 1996) and Kowree (Blackburn & Gibbons 1956 ). Soil sites include West Wimmera, Topcrop sites and NWRS sites. Further inspection sites from West Wimmera should be chased up. | Have used the neighbouring Balmoral sheet to guide units at the boundary, but broad units have been identified from pulling out radiometrics (broader darker areas with sandy surfaces) v. lighter radiometric signatures. Some of the larger waterbody complexes have been pulled out where many occur in close proximity. This is the major focus of these units. Where they are more sparsely scattered they are incorporated into the broader unit. Generally boundaries are reasonably obvious using the radiometrics signature differences between light and dark, or by combining waterbody complexes. However sandy rises, sandsheets, plains, etc. are more difficult to distinguish. In these instances the hydrology has been used as a guide and where minimal hydrology occurs across an area it has been assumed sandy or an elevated sandy plain. | 3 | 3 | 6 |

| Mapsheet | Data used in mapping | Map notes | Mapping reliability (polygonal) | Soil attribution reliability | Combined data confidence level |
|---|---|---|---|---|---|
| Grampians | Overlapping surveys include Rocklands (White et al. 1985) and the Grampians landsystems study by Sibley (1967). Soil sites include WLRA sites and Grampians sites. Overall the area is sparse on soil sites. | High relief of Grampians units defined with combination of DEM and radiometrics. Provides more definition than past linework. Using the White et al. (1985) linework as a base, many of minor drainage line units were amalgamated into surrounding complexes - major drainage lines were still separated out. To the western corner of the sheet the darker radiometrics signature was broadly pulled out from lighter signature areas. These were further refined by referring to the White et al (1985) study and geological changes were used as the basis for defining units. However some areas of complexity e.g. sandsheets, minor dunes, undulating plains, gilgai plains, etc. have been combined as a single complex mapping unit. | 3.5 | 2.5 | 6 |
| Horsham | Overlapping surveys include Badawy's (1997a) mapsheet report/survey, soils mapping of the Wimmera Irrigation Area by Martin et al. (1996), landform mapping by Muller & Hocking (2002a) in addition to soils mapping at Kalkee by Badawy (1977b). Recent mapping by Martin as part of this project was used for the mapsheet as was all previous work in the assembly of this linework. Soil sites are numerous (in total > 4500). | Mapping builds upon landform and soil survey from many studies and sites across the mapsheet. Radiometrics correlates extremely well with linework, only minor alterations made near mapsheet boundaries to complement linework from other studies and vice versa. | 5 | 4 | 9 |

| Mapsheet | Data used in mapping | Map notes | Mapping reliability (polygonal) | Soil attribution reliability | Combined data confidence level |
|---|---|---|---|---|---|
| Ararat<br>Beaufort<br>St Arnaud | Prominent linework for this region includes Rocklands (White et al. 1985) and the Grampians landsystems study by Sibley (1967). Soil sites include WLRA sites and Grampians sites. Overall the area is sparse on soil sites. | High relief of upper Wimmera landscapes units defined with combination of DEM and radiometrics. Provides more definition than past linework. Using the White et al. (1985) linework as a base, many of minor drainage line units were amalgamated into surrounding complexes - major drainage lines are still separated out. These radiometric patterns and soil variations were consistent with new regolith mapping for this area (in particular the Ararat mapsheet). However some areas of complexity included major drainage plains (Mount William Creek), minor dunes, undulating plains, Tertiary weathering surfaces v. Tertiary deposits, etc. have been major mapping issues of these mapsheets. | 4 | 3.5 | 7.5 |

Notes: 1 = low, 2 = low -moderate, 3 = moderate, 4 = moderate-high, 5 = high

Combined data confidence level = Combined total of mapping reliability (polygonal) and soil attribution reliability divided by 2

Equal weighting has been assigned to mapping reliability (polygonal) and soil attribution in this analysis. Values have been assigned by Nathan Robinson from experience in compilation of the Wimmera Land Resource Assessment soil-landform map (2002–2005).

Soil attribution reliability should account not only for density of sites, but also quality of sites (e.g. inspection v. reference sites with chemistry and photography (soil pit)).

# Appendix C Map labels

| Map label | Map unit value | Map unit descriptive name |
|---|---|---|
| Apsley | 1 | Apsley plains |
| Arapiles | 2 | Arapiles steep hills |
| Ararat | 3 | Ararat hills |
| Balmoral | 4 | Balmoral undulating plain |
| Bangerang | 5 | Bangerang prior stream plains |
| Barrabool | 6 | Barrabool sand plains |
| Barton | 7 | Barton lava plains |
| Bellellen | 8 | Bellellen undulating rises |
| Benayeo | 9 | Benayeo gilgai plains |
| Beulah | 10 | Beulah plains |
| Big Desert 1 | 11 | Big Desert dense dunes |
| Big Desert 2 | 12 | Big Desert jumbled dunes |
| Brim | 13 | Brim undulating rises |
| Brimpaen | 14 | Brimpaen undulating plain |
| Broughton | 15 | Broughton undulating plains |
| Charlton | 16 | Charlton gentle rises |
| Concongella | 17 | Concongella hills |
| Darragan | 18 | Darragan rolling rises |
| Diapur | 19 | Diapur ridge |
| Dimboola | 20 | Dimboola rises |
| Donald | 21 | Donald lake and lunettes |
| Dooen | 22 | Dooen eroded plain |
| Douglas l&l | 23 | Douglas lake and lunettes |
| Drung | 24 | Drung alluvial plain |
| Edenhope | 25 | Edenhope undulating plains |
| Elmhurst | 26 | Elmhurst footslopes |
| Fairview | 27 | Fairview plains |
| Glenorchy | 28 | Glenorchy rises |
| Goroke | 29 | Goroke plains and rises |
| Grampians outwash | 30 | Grampians outwash slopes |
| Grampians plains | 31 | Grampians plains |
| Grampians Ranges | 32 | Grampians Ranges |
| Grampians storages | 33 | Grampians storages* |
| Great Western | 34 | Great Western rises |
| Harrow | 35 | Harrow valley |
| Hindmarsh-Albacutya lunettes | 36 | Hindmarsh-Albacutya lunettes |
| Hopetoun | 37 | Hopetoun rises and swales |
| Horsham l&l | 38 | Horsham lake and lunettes |
| Horsham l&l2 | 39 | Horsham lake-lunette cluster |
| Horsham sth fp | 40 | Horsham south flat plains |
| Horsham sth sc | 41 | Horsham south sand-clay plain |
| Horsham township | 42 | Horsham township* |

| Map label | Map unit value | Map unit descriptive name |
|---|---|---|
| Howard Creek | 43 | Howard Creek plains |
| Jerro | 44 | Jerro eroded ridges and slopes |
| Joel South | 45 | Joel South hills |
| Kalkee | 46 | Kalkee plains |
| Kalkee2 | 47 | Kalkee plains 2 |
| Kanawinka | 48 | Kanawinka sandsheets and dunes |
| Kanya | 49 | Kanya hills |
| Kellalac | 50 | Kellalac ridge crests |
| Kiata | 51 | Kiata rises |
| Kowree | 52 | Kowree undulating sand plains and ridges |
| Kybybolite | 53 | Kybybolite plains |
| Landsborough | 54 | Landsborough footslopes |
| Langi Ghiran | 55 | Langi Ghiran Ranges |
| Langi slopes | 56 | Langi Ghiran colluvial footslopes |
| Langkoop | 57 | Langkoop clay plain |
| Lillimur South | 58 | Lillimur South clay plains |
| Little Desert 1 | 59 | Little desert linear dunes |
| Little Desert 2 | 60 | Little desert parabolic dunes |
| Longerenong | 61 | Longerenong prior stream plains |
| Lorquon | 62 | Lorquon undulating plains |
| Lowan | 63 | Lowan salt valley |
| Lubeck | 64 | Lubeck alluvial plains |
| Merryvale | 65 | Merryvale lakes and ridges |
| Minimay | 66 | Minimay plains |
| Mokepilly | 67 | Mokepilly undulating plains |
| Morton | 68 | Morton drainage plains |
| Mosquito Creek | 69 | Mosquito Creek swampy sand plains |
| Mt Cole Creek | 70 | Mount Cole Creek |
| Mt Dryden | 71 | Mount Dryden metamorphic hills |
| Mt William Creek | 72 | Mount William Creek |
| Mt William Creek 2 | 73 | Mount William Creek 2 |
| Murra Warra East | 74 | Murra Warra East gentle rises |
| Murra Warra West | 75 | Murra Warra West gentle rises |
| Murtoa | 76 | Murtoa flats |
| Natimuk-Douglas | 77 | Natimuk-Douglas valley |
| Navarre | 78 | Navarre foothills |
| Neuarpur | 79 | Neuarpur undulating plains |
| Nhill l&l | 80 | Nhill lake and lunettes |
| Nurcoung | 81 | Nurcoung plains |
| Perenna | 82 | Perenna undulating sand plains and rises |
| Powers Creek | 83 | Powers Creek sand plains |
| Pyrenees | 84 | Pyrenees Ranges |
| Quantong | 85 | Quantong dunes and swales |

| Map label | Map unit value | Map unit descriptive name |
|---|---|---|
| Rainbow | 86 | Rainbow hummocky dunes and plains |
| Rhymney | 87 | Rhymney hills |
| Riverside | 88 | Riverside level plains |
| Rocky Point | 89 | Rocky Point low hills and rises |
| Servicetown North | 90 | Servicetown North limestone rises |
| Six-Seven Mile creeks | 91 | Six-Seven Mile creeks |
| St Helens | 92 | St Helens gentle plains |
| Sugarloaf | 93 | Sugarloaf granitic hills |
| Surridge | 94 | Surridge foothills |
| Tallageira | 95 | Tallageira swampy sand plains |
| Telangatuk | 96 | Telangatuk plains |
| Terminal lakes | 97 | Terminal lakes* |
| Ullswater | 98 | Ullswater plains & rises |
| Vectis | 99 | Vectis undulating rises and low hills |
| Wail | 100 | Wail parabolic dunes |
| Wal Wal | 101 | Wal Wal prior stream plains |
| Wartook | 102 | Wartook granite hills |
| Wattle Creek | 103 | Wattle Creek covered plain |
| Werrap | 104 | Werrap lakes and lunettes |
| West Wimmera | 105 | West Wimmera swamp, lake and lunette complex |
| Wimmera River | 106 | Wimmera River |
| Woorak | 107 | Woorak clay plains |
| Yarriambiack-Dunmunkle | 108 | Yarriambiack/Dunmunkle Creek |

* No soil-landform unit description provided

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