Department of Natural Resources, Mines and Energy

Land Resource Assessment of the Upper Logan and Albert Rivers Catchment

South-East Queensland

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Summary

The soils and landscapes of the Upper Logan and Albert Rivers catchment were identified as a critical data gap in the foundational land resource data sets for inland South-East Queensland (SEQ). The data collected in this project (known as the LARA project) can be used to inform and support prioritisation for land degradation rehabilitation, natural resource and catchment management planning, water quality and environmental modelling, as well as local government and regional planning decisions.

Agriculture has a significant presence in the local economy and there are competing land use pressures for both agricultural and urban expansion. The accurate mapping of the land resources and their agricultural suitability supports sustainable management of the state's land, vegetation and water resources. Within this project area there are areas of agricultural and non-agricultural land.

Land degradation is an important consideration for the catchment. Sheet, rill, gully and streambank erosion are evident in all landscapes, particularly on sodic texture-contrast soils where groundcover has been reduced by grazing. Water quality is affected by sedimentation and nutrient delivery to water bodies arising from soil erosion. Secondary salinity expressions were observed primarily in the Upper Logan River subcatchment associated with Walloon Coal Measures geologies.

The project builds on published and unpublished soils and landscape information that was collected between 1971 and 2018 for a variety of purposes within the Logan and Albert Rivers catchment. Soil and landscape attributes were assigned to unique mapping areas (UMAs) based on information collected from 1496 observations, air photo and satellite imagery interpretation, and digital elevation mapping. Conceptual soil profile descriptions, known as Soil Profile Classes (SPCs) and landscape concepts were devised to describe the geomorphic relationship between soils, landforms, lithology and geology.

Soil and landscape attributes were used to assess the agricultural limitations of each UMA allowing the assessment of their suitability for a range of agricultural crops. Agricultural land classes (ALC) were assigned to each UMA by re-interpretation of the land suitability data.

Contents (Volume 1)

Figures (Volume 1)

Tables (Volume 1)

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Acronyms Used in this Report

ALC	Agricultural Land Class
BNH	Land and Agricultural Suitability Assessment of the Boonah Area
BOM	Bureau of Meteorology
CEC	Cation Exchange Capacity
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital Elevation Model
DES	Department of Environment and Science
DNRME	Department of Natural Resources, Mines and Energy
EC	Electrical Conductivity
ESP	Exchangeable Sodium Percentage
GIS	Geographic Information System
KRA	Key Resource Areas
LiDAR	Light Detection and Ranging
MRVBF	Multi-Resolution Valley Bottom Flatness
PAWC	Plant Available Water Capacity
PAWCER	Plant Available Water Capacity Estimation Routine
QLUMP	Queensland Land Use Mapping Program
RE	Regional Ecosystem
REDD	Regional Ecosystem Description Database
SALI	Soil and Land Information Data Base
SDA	State Development Area
SEQ	South-East Queensland
SPC	Soil Profile Class
TPI	Topographic Position Index
TWI	Topographic Wetness Index
UMA	Unique Mapping Area

1. Introduction

The land resources of the Upper Logan and Albert Rivers catchment have been investigated in this project to satisfy the following objectives:

- to compile a soil and land resource foundational dataset, including spatial data and a series of maps
- to evaluate agricultural potential and identify land that is prone to degradation, including land that may be affected by erosion, salinity and invasive weeds
- to assist government, the community and stakeholders with management and planning decisions relating to land resources
- to allow monitoring of soil health.

This project addresses a critical gap in the Queensland Government foundational data set of soils and land resources for South-East Queensland. The study area has been investigated at a variety of scales, due to the varied nature of the area and the differing pressures in parts of the catchment. Land suitability has been assessed and an Agricultural Land Class (ALC) has been allocated to all of the Unique Mapping Areas (UMAs) in this project.

The results of this project will inform and support a range of applied science, planning and natural resource management decisions through the application of knowledge in landscape processes, geology, soil forming processes and land use/land management interactions. Catchment processes, soil/land attributes and ALC have been documented. Mapping has used field refined 1:100 00 scale geology and landform data in association with site-specific, soil and landscape field data collected during the course of the study, and reinterpretation of existing site data. The data outputs from this project support:

- local landholders through access to better information to make informed land management decisions affecting property planning, agricultural productivity, vegetation management land degradation, environmental and water quality outcomes
- improved decision making by Seqwater in relation to the management and operation of water storages and their surrounding lands
- the Scenic Rim Regional Council land use decision making
- investment in natural resource planning and allocation decisions
- the Queensland Government's Open Data Policy and the accurate and timely supply of property and spatial information resources.

The soils data collected in this project and stored in the Queensland Government soil and land information (SALI) database including site data, agricultural land suitability and ALC is available digitally via web based services.

A variety of other land resource projects have been completed in SEQ over the past 40 years. Relevant projects surrounding LARA are displayed in Figure 1 and include:

- *Soils and land suitability Albert River* (Malcolm *et al.* 1998)
- *Irrigation suitability of Teviot Brook area, Boonah* (Christianos *et al.* 1986)
- *Land and agricultural suitability assessment of the Boonah area* (Loi *et al.* 2005)
- *Understanding and managing soils in the Moreton Region* (Noble 1996 ed.)

Figure 1. LARA project extent and surrounding land resource projects.

2. Study Area

The project area is dissected diagonally from SW to NE by the Logan River from its headwaters in Mt Barney National Park to the peri-urban fringe of Logan City at Chambers Flat (Figure 2). South of Beaudesert, the Logan River generally marks the boundary between steep hills of volcanic origin to the east and more rounded hills of sedimentary geological units to the west. The south-west corner of the area is dominated by several igneous intrusions resulting in Mt Barney, Mount Gillies, Mount Maroon and other distinctive peaks.

The Land Resource Assessment of the Upper Logan and Albert Rivers Catchment study area (Figure 3) includes all of the Albert River catchment above Luscombe Weir and the majority of the Logan catchment above Chambers Flat. The irregular western boundary of the study area marks the boundary of a previous study, the *Land and Agricultural Suitability Assessment of the Boonah area* (BNH) (Loi *et al*. 2005). The subcatchments of Teviot Brook and the upper reaches of Allan Creek, Cannon Creek and Burnett Creek on the Logan system were incorporated into the BNH study. The northern boundary of the study area approximately marks the current boundary between agricultural land use and urban and peri-urban subdivisions.

Figure 2. Irrigated dairy farm at Chambers Flat with rural residential development in distance

To the north of Beaudesert, rounded sedimentary hills and wider alluvial plains dominate the landscape, with a small area of steep hills in the north-east corner of the study area formed from Devonian and Carboniferous metamorphic rocks.

The majority of the study is within the Scenic Rim Regional Council area, with the exception of a small section in the north that is part of the Logan City Council local government area (Figure 11).

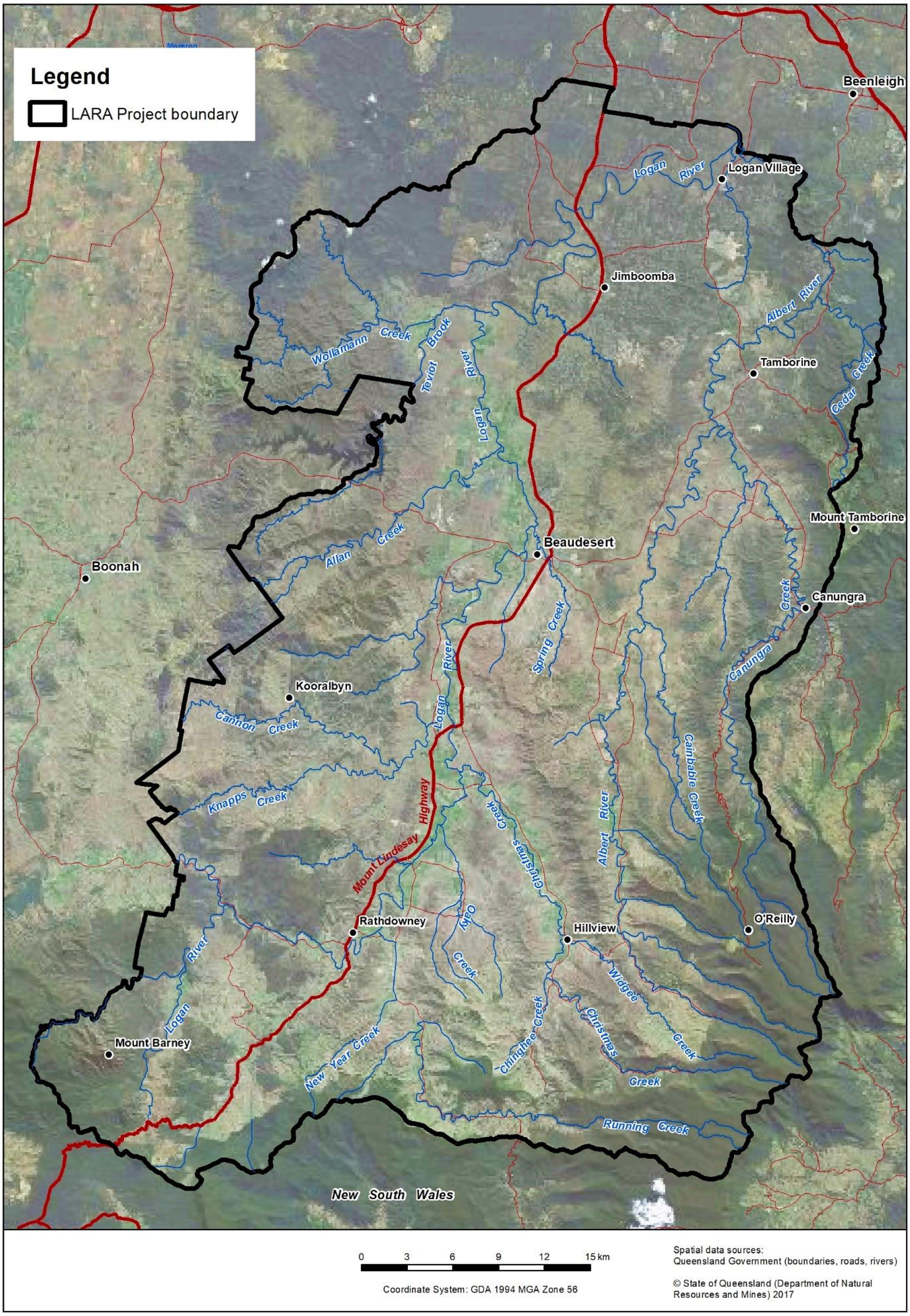


Figure 3. LARA project area.

3. Climate

The Logan and Albert Rivers catchment experiences a sub-tropical climate, typically with warm wet summers and mild dry winters. Daytime temperatures range between daytime averages of mid 30ºC in summer, to 20ºC in winter (BOM 2019) (Figure 4). Cooler summer temperatures are experienced on the higher elevations of the Border Ranges.

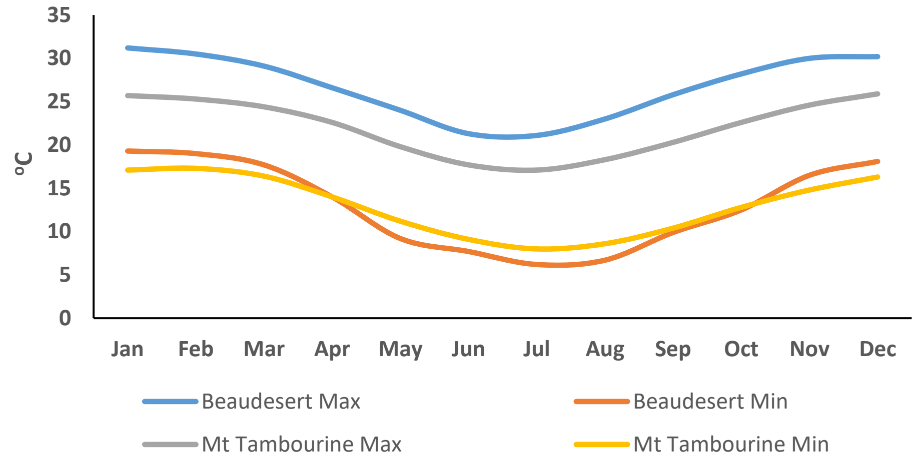


Figure 4. Regional monthly average temperatures.

High average annual rainfall of over 1000 mm is experienced on higher peaks and in the Border Range area particularly in the headwaters of Christmas Creek, Widgee Creek and Running Creek. More moderate rainfall (850-900 mm) occurs on the slopes and valleys of the Upper Logan and Albert Rivers catchment (BOM 2019). The town of Beaudesert has an average annual rainfall of 916 mm (Figure 5 & Figure 6).

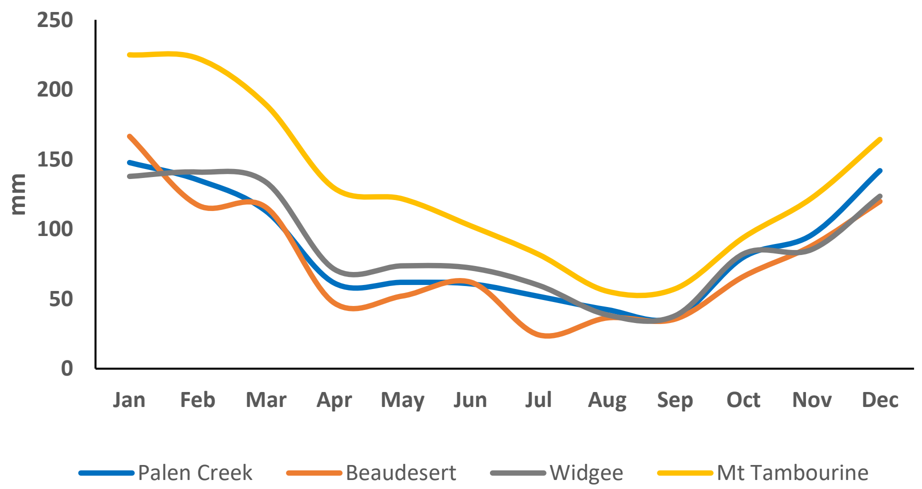


Figure 5. Regional monthly average rainfall.

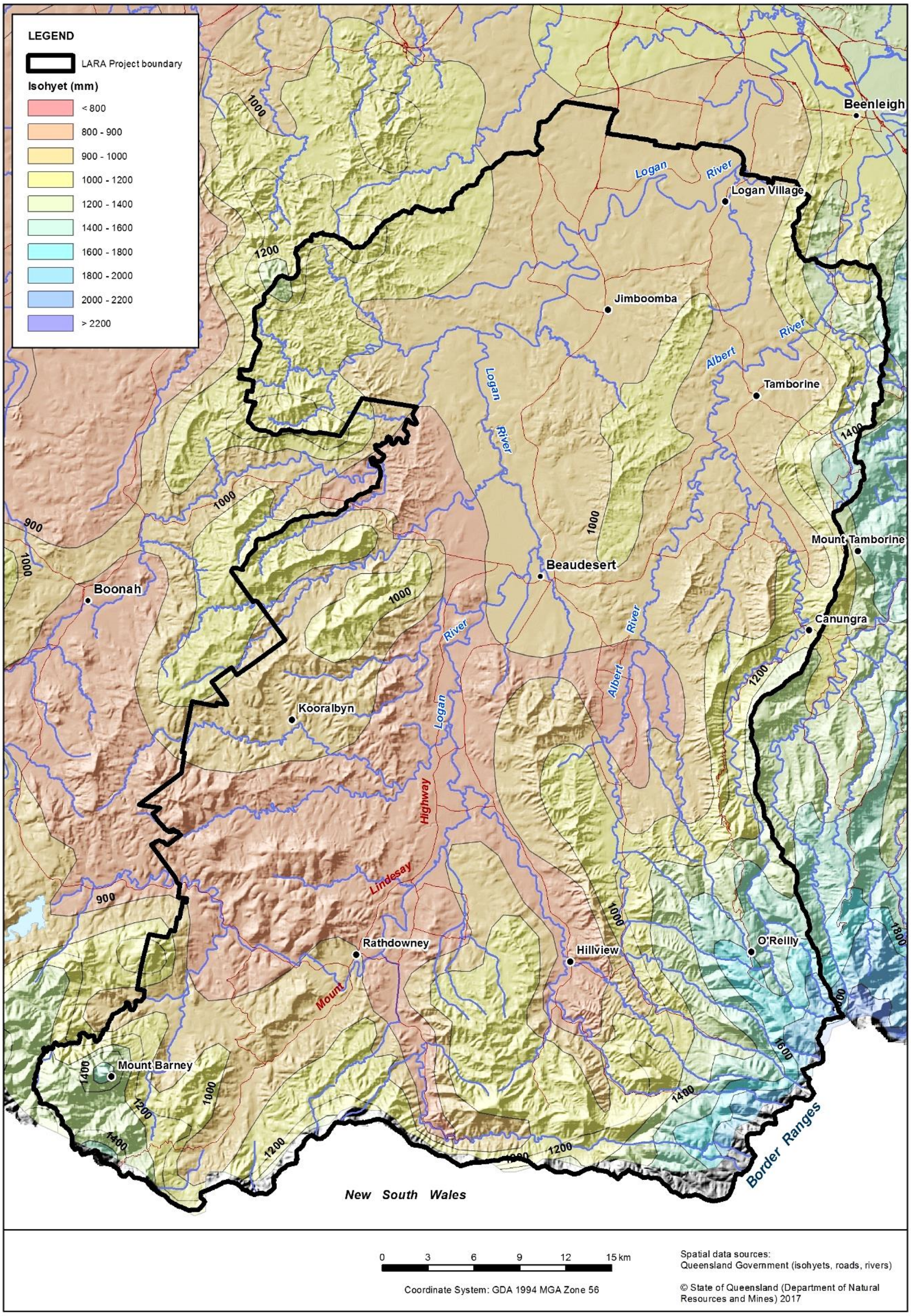


Figure 6. Annual average rainfall isohyets in the LARA project area.

4. Hydrology

The study area follows the catchment of the upper Logan and Albert Rivers. It includes the Logan River tributary streams of Widgee Creek, Christmas Creek, Running Creek, Palen Creek, Burnett Creek, Knapp Creek, Sandy Creek and Allen Creek, and the Albert River tributaries of Kerry Creek, Cainbable Creek and Canungra Creek. The headwaters of the Logan and Albert Rivers are in the McPherson Range, largely in conservation areas including the World Heritage Listed Gondwana Rainforests of Australia. Stream flow volumes are presented in Figure 7.

The high rainfall in the headwaters of Christmas Creek, Widgee Creek and Running Creek on the Logan system and Canungra Creek, Cainbable Creek and the branches of the Albert River, combined with good recharge of groundwater due to the basalt geology, results in near permanent flows in these waterways.

Groundwater resources in the study area are confined to the Quaternary alluvial aquifers of the Logan and Albert Rivers. The Walloon Coal Measures have low bore yields and generally brackish to saline groundwater (the main permeability zones of this aquifer are associated with the coal seams). The overlying Marburg Sub-Group (the Koukandowie Formation and Gatton Sandstone) has similar yields and supplies of brackish to saline groundwater. However, the sequence of sandstones underlying the Marburg Sub-Group (the Woogaroo Sub-Group) has some known porous sandstone aquifers that yield water of variable quality (salinity of 500 to 2000 µS/m) at various flow rates (Helm *et al.* 2009).

Alluviums where groundwater is available range in depth between 10 and 27 m and contain a sandy/gravel aquifer at the base of the sequence. Groundwater flow is in a northerly direction (Please *et al.* 1996). The typical salinity in the Logan and Albert Rivers alluvium is in the range of 0.8 to 4.0 dS/m (500 to 2600 mg Cl/L) with a significant increase since the 1950s in some parts. There is currently a limited understanding of these surface water-groundwater interactions (Rassam *et al.* 2018).

Groundwater is used primarily for irrigation and farm use throughout the region (Figure 8) with some use in industrial processing plants at Bromelton. Groundwater systems are monitored under the Water Resource (Logan Basin) Plan (DNRW 2007), however, groundwater use is not regulated in the study area.

Irrigators in the Logan catchment also have access to water through the Logan River Water Supply Scheme. Maroon Dam was designed to supplement natural flows for the alluvial farming areas along Burnett Creek and the Logan River. The scheme includes 101 km of the Logan River and 30 km of Burnett Creek. Water is also allocated to irrigators in the Christmas Creek and Running Creek water management areas. These schemes are regulated under the Logan Basin Resource Operations Plan (DNRM 2009).

The Logan and Albert Rivers are the source of domestic water to a number of towns in the region. Water treatment plants supply water from the Logan River to Palen Creek Correctional Centre, and the communities of Rathdowney, Kooralbyn and Beaudesert. Canungra water treatment plant draws water from Canungra Creek upstream of the township. Variable water quality creates challenges for the water treatment plants (Department of Environment and Science 2015a, b, c) and all five plants were ‘offline’ during the Cyclone Debbie flooding of March 2017.

Sewage treatment plants return treated water to the Logan River at Kooralbyn and Beaudesert, and at Canungra on the Albert system (Department of Environment and Science 2015a, b, c, d).

Healthy Land and Water (2017a, b) reports the overall environmental condition of the Logan and Albert River as fair, with a slight decline over previous years due to an increase in pollutant loads and decrease in freshwater stream health. However, the Australian Government Bioregional Assessment for the Clarence-Moreton bioregion reports that the Logan and Albert Rivers system exports the highest amount of nitrogen per unit area for the region (Rassam *et al.* 2018).

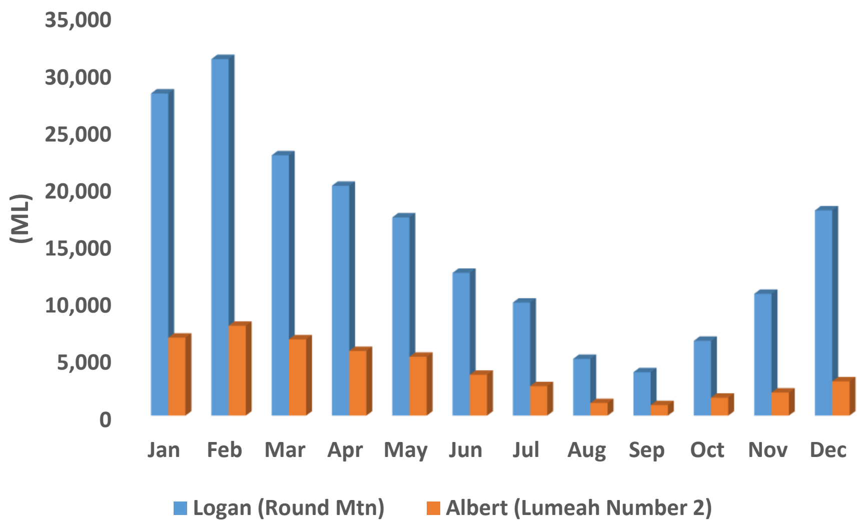


Figure 7. Stream flow volumes for Logan and Albert Rivers.

Figure 8. Irrigated turf farm on the Logan River floodplain at Allan Creek.

5. Land Use and Population

5.1. Land use

The Logan and Albert Rivers region was explored by Captain Patrick Logan in 1826 who initially named the Logan River the River Darling in honour of the Governor of NSW. The name was changed (by Governor Darling) to the Logan River in 1827. To the Yugambeh Aboriginal people of the region, the river was known as Dugulumba (Griffith University 2018).

Settlement began in the Logan and Albert Rivers area in the early 1840s, and by 1861 Lt. Wheeler of the Queensland Native Mounted Police indicated that he had 'dispersed' the Logan River Aboriginals from their lands. A small echo of pre-settlement times remains in Indigenous place names across the region such as Nindooinbah (Place of the remains of a fire/hearth) and Tabragalba (Place of nulla-nullas) (Watson 1943).

Following the opening of Brisbane to free colonists in 1842, the first settlers in the Logan and Albert catchment district were timber getters and squatters (occupiers of crown grazing land beyond the prescribed limits of settlement prior to the issue of leases). The valuable timber of the red cedar *(Toona ciliata)* was soon depleted and hoop pine (*Araucaria cunninghamii*) was the next species exploited followed by hardwood species as the hoop pine became scarce. Prior to the establishment of roads and timber mills in the region in the late 1880's, the Logan and Albert Rivers were used to transport logs to the coast where they were collected and rafted to Brisbane (Hart 1959).

Land leases in the district were issued from1849 and until the 1860s sheep and beef cattle production were the dominant activities. By the early 1900s larger estates of freehold land were subdivided and timber harvesting and agriculture, particularly dairying, became more important. From the 1960s to the present time, there has been a shift away from dairy farming to beef cattle grazing (Figure 9).

Figure 9. Common land use examples - beef cattle grazing at Bromelton (Site 2197) and irrigated cropping at Tamrookum (Site 531).

The majority of the non-urban land in the project area is within the Scenic Rim local government area, with 161 000 hectares (Table 1 and Figure 10) cleared for cattle grazing on native pastures. The most prominent remaining agricultural practices in the region are irrigated cropping, dairy farming, plantation forestry, thoroughbred horse breeding and training, and irrigated turf farming. However, there has been a significant increase in the number of intensive poultry farms since 2000 (29 farms in existence in 2012). Poultry farming generates the highest agricultural incomes in the region followed by beef cattle production (Scenic Rim Regional Council 2018).

State defined Priority Agricultural Areas (PAAs) are located within the project area on the alluvial plains of the Logan and Albert river systems (Figure 12). The Queensland Regional Planning Interests Act (Department of Infrastructure, Local Government and Planning 2014) defines PAAs as; "areas of regionally significant agricultural production that are identified in a regional plan".

In 2016 agriculture and forestry made the largest contribution to the gross regional product of the area with $403 million (22.7%) (Trade and Investment Queensland 2017).

A growing tourist industry including camping, bushwalking, farm-stays and scenic drives, is based on over 27 000 ha of National Parks in the upper parts of the catchment, including Mt Barney National Park and Lamington National Park. The World Heritage Border Ranges National Park contains unique vegetation remnants which also provide a range of ecosystem services such as flood protection, groundwater recharge and significant biodiversity. The Scenic Rim Council area received over 1.3 million visitors in 2016 bringing about $177 million to the region. Tourist numbers have been increasing at 3.3% a year since 2010 (Scenic Rim Regional Council 2017).

There are 4 hard rock quarries in the Beaudesert/Bromelton area, designated as Key Resource Areas (KRA) under the State Planning Policy (Department of Infrastructure, Local Government and Planning 2017). They are KRA 61, KRA 139, KRA 140 and KRA 142 and are known as Bromelton, Cryna, Erin View and Markwell Creek Road quarries respectively. There are also two hard rock quarries in the Darlington Range to the east of Cedar Creek.

Table 1. Major land uses in the Scenic Rim local government area (QLUMP 2012)

Land use	**Area (Ha)**
Grazing native vegetation	161 064
National park	27 914
Rural residential without agriculture	20 881
Residual native cover	17 197
Irrigated cropping	6336
Rural residential with agriculture	4629
Grazing irrigated modified pastures	3935
Plantation forests	2658
Recreation and culture	1993
Other conserved area	1562
Land in transition	1200
Horse studs	1136
Grazing modified pastures	1032
Reservoir/dam	938
Irrigated turf farming	778
Total	253 253

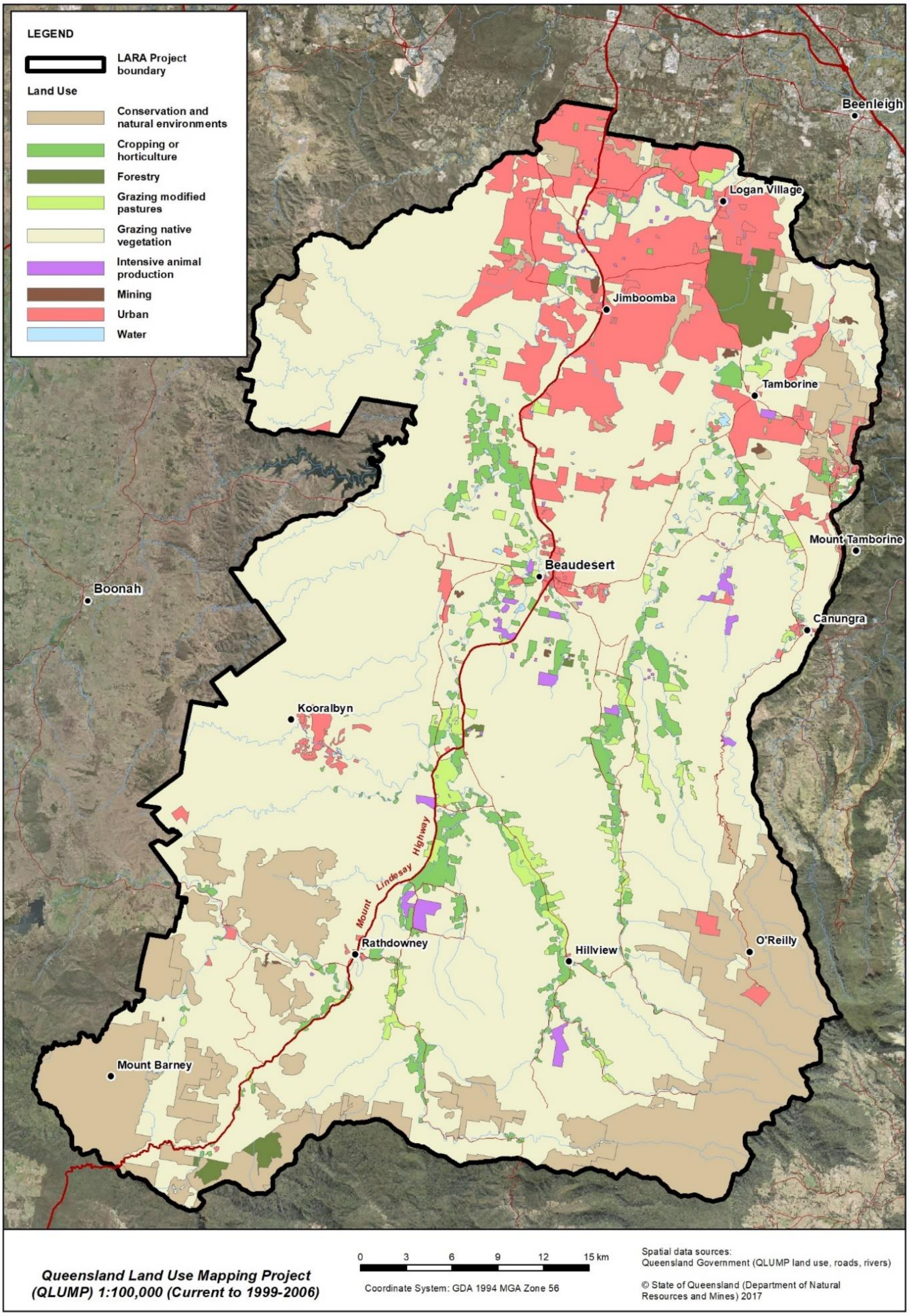


Figure 10. LARA project land use mapping.

5.2. Vegetation on the Devonian/Carboniferous metamorphic rocks of the Neranleigh–Fernvale Formation

A small area of steep hills, to the east of Cedar Creek (in the north-east of the project area) between the coastal plain and the Albert River, rise to rounded peaks of 350 to 380 m elevation and form the northern extent of the Darlington Range.

On steep slopes and in sheltered gullies, a mixed eucalyptus open forest occurs with some vine forest species occurring in the gullies. This RE (12.11.3) is known as *Eucalyptus siderophloia* (grey ironbark)*, E. propinqua* (grey gum) *+/- E. microcorys* (tallowwood)*, Lophostemon confertus* (brush box)*, Corymbia intermedia* (pink bloodwood)*, E. acmenoides* (white mahogany) open forest.

The most extensive vegetation type in this area is composed of regrowth based on the former RE 12.11.10 notophyll and notophyll/microphyll vine forest +/- *Araucaria cunninghamii* (hoop pine). This vegetation was observed on the lower slopes and valleys often accompanied by dense growths of *Lantana camara* and other weeds.

Due to the steepness of the hills, most of the access tracks in the region follow the ridges where the shallow, gravelly soils support *Corymbia citriodora* subsp*. variegata* (spotted gum) open forest to woodland, usually including *Eucalyptus siderophloia/E. crebra* (narrow leaf ironbark)*, E. propinqua* and *E. acmenoides* or *E. carnea* (thick leaf mahogany) (RE 12.11.5) (Figure 20).

5.2.1. Minor Triassic units

5.2.1.1. Chillingham Volcanics

The Chillingham volcanics are mainly comprised of rhyolite, lithic rhyolitic tuff and shale and have only a very small extent in the far north-east adjacent to the older Neranleigh-Fernvale Beds. Part of a larger unit, they extend south into New South Wales. Soils formed on this geology mirror those of other rhyolite geologies such as the Mount Gillies Volcanics (Tfg).

5.2.1.2. Ipswich Coal Measures

The late Triassic Ipswich Coal Measures (Ri), sandwiched between the Chillingham Volcanics (Rch) and the Woogaroo Subgroup (RJbw), are another geology that only occurs in a small and confined area of the project. They are an extension of the same geology found further west and are located in the far north-east adjacent to the older Neranleigh-Fernvale Beds. A mixed unit consisting of shale, conglomerate, sandstone, coal, siltstone basalt and tuff, these sediments were often mined for their coal resource.

5.2.2. Triassic to Jurassic sediments

A long period of sedimentation throughout the Jurassic period (213-144 million years ago) resulted in the formation of the Moreton Basin with the deposition of the Woogaroo Subgroup (RJbw), followed by the Marburg Subgroup (Jbm) and the Walloon Coal Measures (Jw). Subsequent folding has resulted in rounded sandstone hills in the Woogaroo Subgroup and Marburg Subgroup and more gently undulating landscapes where the Walloon Coal Measures outcrop (Willmott 1992).

The thick beds of the Woogaroo Subgroup are composed of fine to coarse sandstone with a few thin beds of conglomerate, particularly near the base. The Marburg Subgroup is composed of generally narrower beds of coarse to fine grained sandstones and finer sediments of siltstone and mudstone and has been subdivided into the lower (older) Gatton Sandstone (Jbmg) and the upper (younger) Koukandowie Formation (Jbmk) (Jell 2013).

The Gatton Sandstone is predominately thick-bedded, medium and coarse grained quartz-lithic and feldspathic sandstone with small occurrences of siltstone. The Koukandowie Formation is composed of sandstone, siltstone and shale.

Soils derived from the Gatton and Koukandowie formations have low fertility and exhibit major to severe erosion. Sheet and gully erosion was particularly evident in the Knapp Creek catchment (see Land Degradation section).

The youngest unit in this group is the Walloon Coal Measures, which consists of a sequence of grey fine grained sediments including mudstone, siltstone, shale, fine sandstone and coal. Clay types found in these finer sediments may indicate the presence of volcanic activity prior to their deposition (Gould 1968). Economic coal seams occur in the Walloon Coal Measures in other regions, however no extraction of coal occurred in the study area.

5.2.3. Beaudesert Beds

These Miocene sediments are confined to an area approximately between Beaudesert and Woodhill, where they are intimately associated with deeply altered basic igneous rocks and consist of coarse cobble conglomerate, sandstones, siltstones, and very thinly bedded carboniferous shales. The relationship of the different types of bed-rock to one another is extremely complex and as each type of rock gives rise to its own type of soil, the soil pattern is also complex (Paton 1971).

5.2.4. Neogene sediments

The Neogene sediments (Ts) are isolated, small in size (a total of 540 hectares) and located along the eastern slopes of the Birnam Range, near Mount Dunsinane, with another small area at Kerry. They comprise quartzose to sublabile sandstone, claystone, conglomerate and minor olivine basalt.

5.2.5. Late Neogene to Pleistocene colluvium

Small but agriculturally significant areas of colluvial materials were deposited at the base of hillslopes by mass movement erosion or hillslope collapse under conditions of intense rainfall in the late Neogene to early Pleistocene period (approximately 5 million to 50 000 years ago). While basalt materials dominate these colluviums (from Albert, Hobwee and Beechmont Basalts) areas formed from sandstone and siltstone (from Walloon Coal Measures), rhyolite (from Mount Gillies volcanics) and greenstone (from Neranleigh-Fernvale Formation) are also present. Materials deposited on these lower slopes range from sand, silt and clay materials (TQr), to large boulders and rocks (TQcb), which are also now weathering to soil. Figure 18 indicates the lower landscape position occupied by this colluvium relative to the older low hills and hills above it and the younger alluvium deposited below.

5.2.6. Pleistocene to Holocene alluvial plains

The Quaternary alluvial (Qa) deposits of clay, sand and gravels form the youngest geological units of the study area. These deposits are largely unconsolidated and generally overlie older geologies at various depths, usually infilling valleys adjacent to current or relict streams. As with all alluviums their parent or donor material is the overriding factor determining their nature.

Available groundwater bore log data indicates coarse sands and gravel at the base of the alluvial sequence, with fine-medium sands, then silts and clays towards the surface (Rudorpher 2009). A typical bore log for Logan River alluvium at Tamrookum is shown in Figure 19, note the depth of more than 20 m (BOM 2019).

5.3. Population

The population of the Scenic Rim local government area (Figure 11) is 40 072 (0.10 persons per hectare) and is forecast to grow by 100 per cent to 78 100 residents by 2031 (Queensland Urban Utilities 2014). The main urban population centres in the project area are Beaudesert (population 5823) and the townships of Kooralbyn (population 1684), Gleneagle (population 1327), Canungra (population 784), Tamborine (population 473) and Rathdowney (population 434). These townships provide basic services to the surrounding rural areas (Australian Bureau of Statistics 2016).

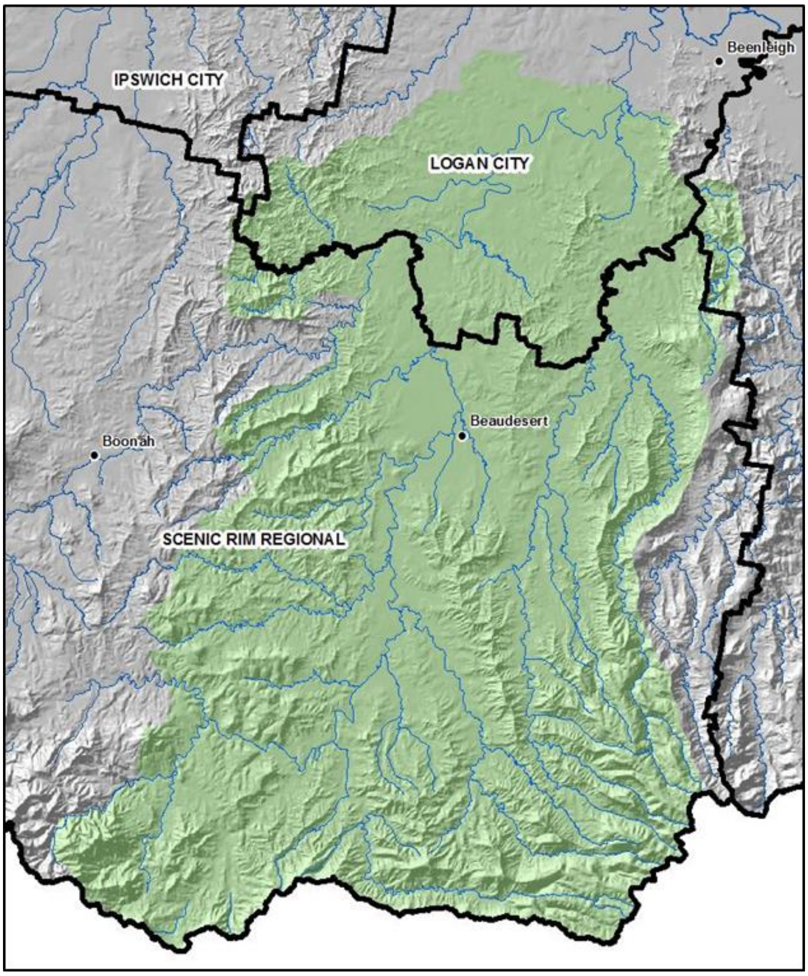


Figure 11. LARA project area local government boundaries.

Population density is greater in the Logan City Council region (3.33 persons per hectare) with major centres within the study area located at Jimboomba (population 13 204), Logan Village (population 4418), New Beith (population 4088), Tamborine (north of the Logan River) (population 3944) and Yarrabilba (population 3578) (Logan City Council 2018).

Two significant urban developments designated as Priority Development Areas (PDA) are occurring in the north of the project area in the Logan City Council region (Figure 12). Greater Flagstone near the township of Jimboomba will cover an area of 7188 hectares and is planned to house up to 120 000 people in 50 000 dwellings, and Yarrabilba, 20 km to the south of Logan Central, will house up to 50 000 people in 20 000 homes. Smaller urban developments are also underway in the Scenic Rim Council region on the fringes of Beaudesert and Canungra. Peri-urban, or non-agricultural rural residential land is also a significant component of land use at 20 880 hectares (Department of Science, Information Technology and Innovation 2016).

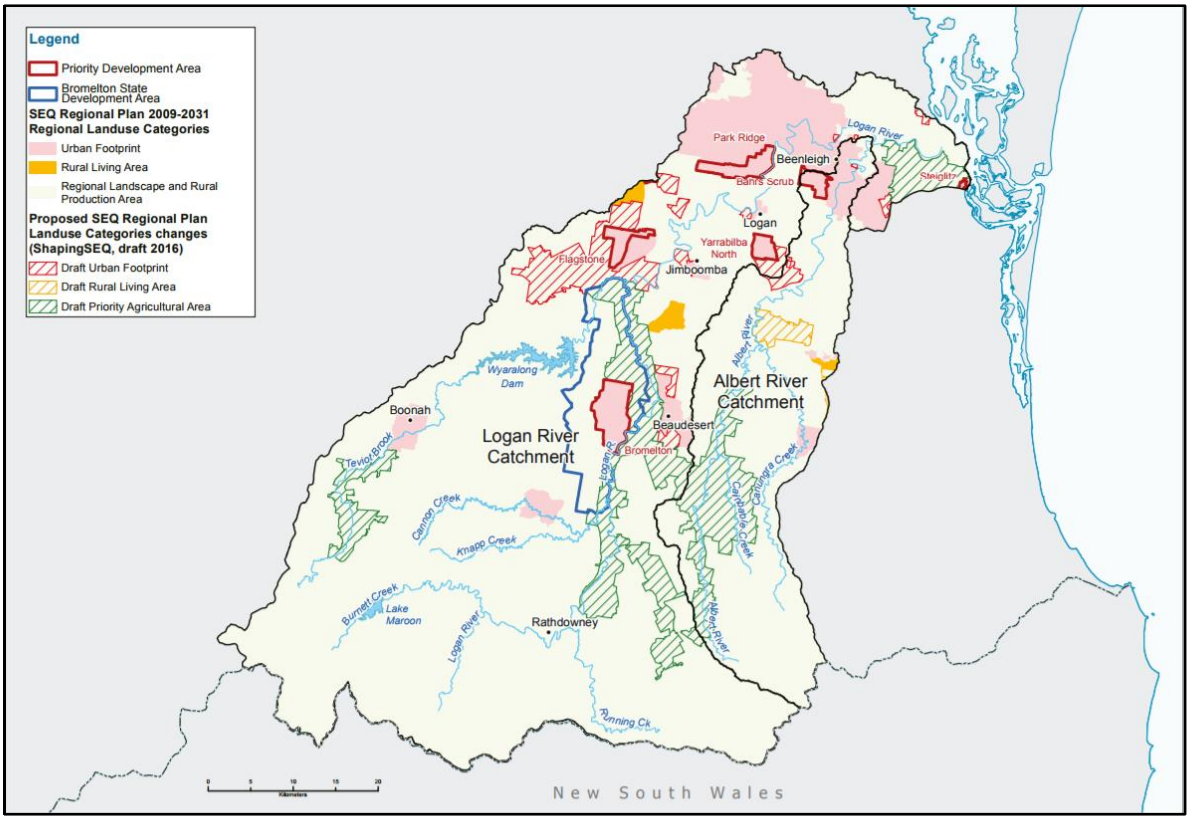


Figure 12. Regional land use categories (source Resilient Rivers Initiative 2017)

Six kilometres west of Beaudesert, the Bromelton industrial estate, located on the Sydney–Brisbane rail corridor, is designated a State Development Area (SDA). Currently home to a quarry, a rendering plant (Figure 13), a gelatine factory and other rural-related industries, the Bromelton SDA is zoned for medium to large industries and will occupy up to 15 610 hectares.

Figure 13. Rendering plant at Bromelton

6. Geology

The project area lies within the Clarence-Moreton Basin and the eastern part of the great artesian basin (GAB). It contains various sedimentary formations, intrusive and extrusive volcanics and younger colluvial and alluvial deposits. Anticline activity has exposed the lower rocks of the Triassic-Jurassic sediments (Woogaroo and Marburg subgroups) and this is flanked by complementary synclines containing younger and generally finer-grained rocks of the Jurassic Walloon Coal Measures (Figure 14) and Tertiary (Neogene) sedimentary and igneous rocks (Paton 1971; Wells & O'Brien 1994). The rocks of the anticline form rugged hill country, while the synclines give rise to gently undulating lowlands (Paton 1971; Jell 2013).

6.1.1. Neogene (Miocene) volcanics

It is believed that the first basalt flow originated approximately 24 million years ago from vents of a volcano known as Focal Peak situated to the west of Mt Barney. The mobile Albert Basalt (Tfa) lava flowed down broad north-south valleys as far as Beaudesert in the north, to Tamborine in the north-east and south to Kyogle. Later and more explosive eruptions of vents on the eastern side of the Focal Peak formed the rhyolite dominant Mount Gilles Volcanics (Tfg). There are also numerous smaller rhyolite and trachyte intrusions in the Mt Barney Volcanic Field.

In a second stage of this volcanic activity, a previously formed granophyre batholith was pushed to the surface through the deep sediments of the Carboniferous Mt Barney Beds (Cy), forming Mt Barney (Figure 16). In doing so these sediments were uplifted, along with the overlaying Jurassic sediments of the Marburg Subgroup (Jbm), resulting in steeply inclined meta-sediments and sediments circling the Mt Barney peak (Stevens and Willmott 1998) following the line of a now obvious ring fault.

The larger Tweed Volcano, centred over the existing Mt Warning, south-east of Mount Lindesay, was the source of later basalt flows resulting in the deposition of the higher elevation Beechmont (Tlb) and Hobwee Basalts (Tlh). This shield volcano produced deep flows over a large area, including the area between Mount Lindsay and Mount Tambourine in the project area (Willmott 1992). The flows were thicker close to the source but thinned towards their edges.

A pattern of radial streams influenced subsequent erosion eventually exposing each of the lava flows and underlying sedimentary formations. (Figure 17). The weathering and erosion of these basalt lavas has resulted in deep fertile soils, especially in alluvial river valleys, that have been largely cleared for agriculture.

Around the same time, a series of mafic, intermediate and acidic intrusive rocks of small extent formed isolated but defined hill and mountain features (Paton 1971) from Mount Maroon to Flinders Peak along the western edge of the study area (rhyolite (Ti, Tir), trachyte (Tit), syenite (Tis) and dolerite (Tid)) and at Cainbable Creek (rhyolite (Tir)) and Cedar Creek in the east (basalt (Tib)).

6.2. General distribution

South of Beaudesert, the major geological units are divided by the valley of the Logan River with Triassic-Jurassic sediments predominating to the west and the overlying Miocene basalt flows evident to the east. The region around Mt Barney (a granophyre dome) has several intruded rhyolite sills including Mt Ernest, Mt Maroon and Mt May. To the north of Beaudesert, there is a small area of complex Neogene sediments, known as the Beaudesert Beds, overlying the widespread Triassic-

Jurassic sediments. In the north-east corner of the study area steep hills of the Darlington Range are formed by the older Devonian/Carboniferous Neranleigh-Fernvale Beds (Figure 15).

Figure 14. Narrow coal seam in Walloon Coal Measures in the bank of Palen Creek (Site 2015).

6.3. Geology overview

The following sections detail the significant geological groups in the study area. Table 2 contains a summary of these groups arranged according to age.

Table 2. Summary of geological units in the study area

Geological unit and symbol	General geological grouping	Area in study area (ha)	Landform	Lithology	Age (ERA/Period)
Neranleigh- Fernvale beds (DCf)	Meta-sedimentary rocks	5065	Steep hills & mountains	Arenite, sandstone, mudstone, chert, greenstone, greywacke, quartzite	PALEOZOIC Early Carboniferous to Late Devonian
Mount Barney Beds (Cy)	Sedimentary and calc-silicate rocks	1520	Rolling low hills to hills	Sandstone, mudstone, siltstone, interbedded rhyolite/trachyte	PALEOZOIC Late Carboniferous
Chillingham Volcanics (Rch)	Siliceous volcanic rocks	205	Rolling to steep low hills to hills	Rhyolite, rhyolitic tuff, shale	MESOZOIC Late Triassic
Ipswich Coal Measures (Ri)	Sedimentary rocks	2511	Undulating to rolling rises to low hills	Shale, conglomerate, coal, siltstone	MESOZOIC Late Triassic
<u>Bundamba group</u>					
Woogaroo Subgroup (RJbw)	Fine to coarse sedimentary rocks	13 306	Undulating to rolling rises to low hills	Quartzose sandstone, siltstone, shale	MESOZOIC Late Triassic to Early Jurassic
Marburg Subgroup (Jbm) (Gatton Sandstone (Jbmg) & Koukandowie Formation (Jbmk))	Medium to coarse sedimentary rocks	84 197	Rolling rises to steep hills	Quartzose or felspathic sandstone, siltstone, shale	MESOZOIC Early to middle Jurassic
<u>Injune Creek group</u>					
Walloon Coal Measures (Jw)	Fine grained sedimentary rocks	18 457	Undulating to rolling rises to low hills	Siltstone, mudstone, shale, fine sandstone, coal	MESOZOIC Middle to Late Jurassic
Beaudesert Beds (Te)	Lacustrine sediments	3054	Undulating to rolling rises to low hills	Conglomerate, sandstone, siltstone, shale, basalt	TERTIARY Neogene
<u>Lamington Volcanics</u>					
Albert Basalt (Tfa)	Mafic volcanic rocks	50 388	Rolling to steep hills to mountains	Olivine basalt	TERTIARY Neogene
Chinghee Conglomerate (Tfg/c)	Lacustrine sediments	3778	Rolling to steep hills to mountains	Coarse sandstone and conglomerate	TERTIARY Neogene
<u>Lamington Volcanics continued</u>					
Mount Gillies Volcanics (Tfg)	Siliceous volcanic rocks	2179	Rolling to very steep hills	Rhyolite, basalt, tuff	TERTIARY Neogene
Mount Barney Central Complex (Tbgr/Tbsr)	Siliceous volcanic rocks	541	Rolling to steep rises to hills	Granophyre, rhyolite, trachyte	TERTIARY Neogene
Hobwee Basalt (Tlh)	Mafic volcanic rocks	11 497	Rolling to steep rises to hills	Olivine basalt	TERTIARY Neogene
Beechmont Basalt (Tlb)	Mafic volcanic rocks	13 613	Rolling to steep hills to mountains	Olivine basalt	TERTIARY Neogene
<u>Colluvium</u>					
Older residual deposits (TQr)	Colluvium	2564	Rolling to steep low hills to mountains	Clay, silt, sand, gravel	TERTIARY/ QUATERNARY Neogene/ Pleistocene
<u>Alluvium</u>					
Terraces and alluvial plains	Alluvium	40 416	Level to gently undulating plains, terraces and flood plains	Clay, silt, sand, gravel	QUATERNARY Pleistocene to Holocene

6.3.1. Devonian/Carboniferous metamorphosed rocks of the Neranleigh-Fernvale Beds

The Neranleigh-Fernvale Beds (DCf) are the oldest formation in this study area and are composed primarily of folded and steeply inclined meta-sedimentary rocks (metamorphic rock of sedimentary origin). The study area includes a small area of this geology in the form of steep hills of the Darlington Range to the east of Cedar Creek in the north-east. Lithology (Table 2) ranges from arenite (sandstone) to mudstone, chert and greenstone. The hardness of these metamorphic rocks, particularly the greywacke, quartzite and greenstone, make them an important source of crushed rock aggregate for road and construction uses (Willmott 1992).

6.3.2. Mount Barney Beds

This is a small area of steeply dipping Carboniferous (approximately 350 million year old) sediments to the east and west of the base of Mount Barney that were violently uplifted by the emergence of the mountain. The unit comprises several deposited sediment layers including calc-silicate rocks (possibly limestone metamorphosed by the intrusion of Mount Barney), sandstone, mudstone and siltstone with rhyolite/trachyte interbedding. Total depth of these beds likely exceeds 2000 m (Jell 2013).

6.4. Geology and soils

For the remainder of this report the geological structure outlined in section 6.2 has been maintained and is used to aid reporting on vegetation, soils and landscapes. Where appropriate, further delineation into lithology groups or sources of alluvium has been implemented.

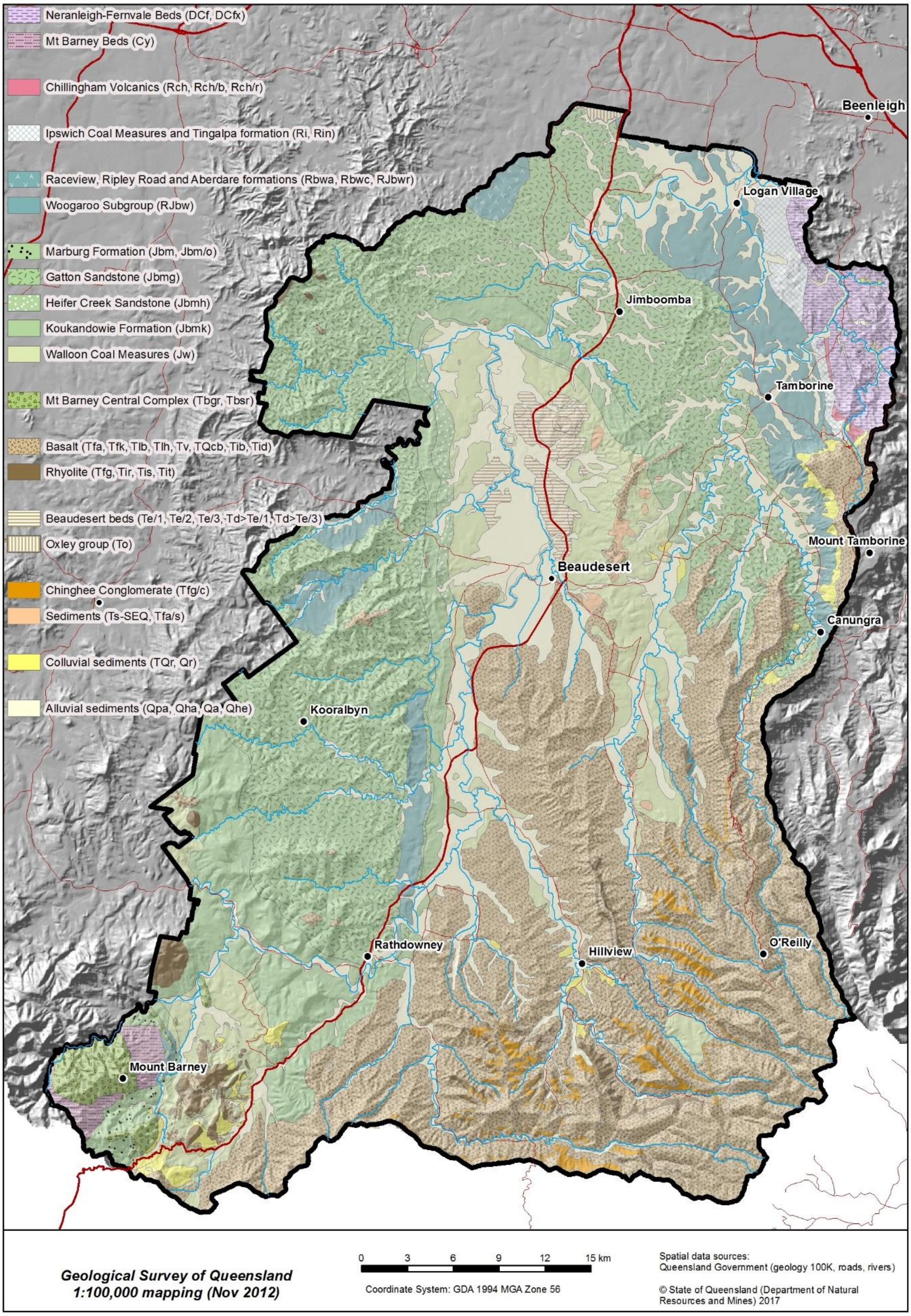


Figure 15. Geology of the LARA project area.

Figure 16. The distinctive granophyre peak of Mt Barney.

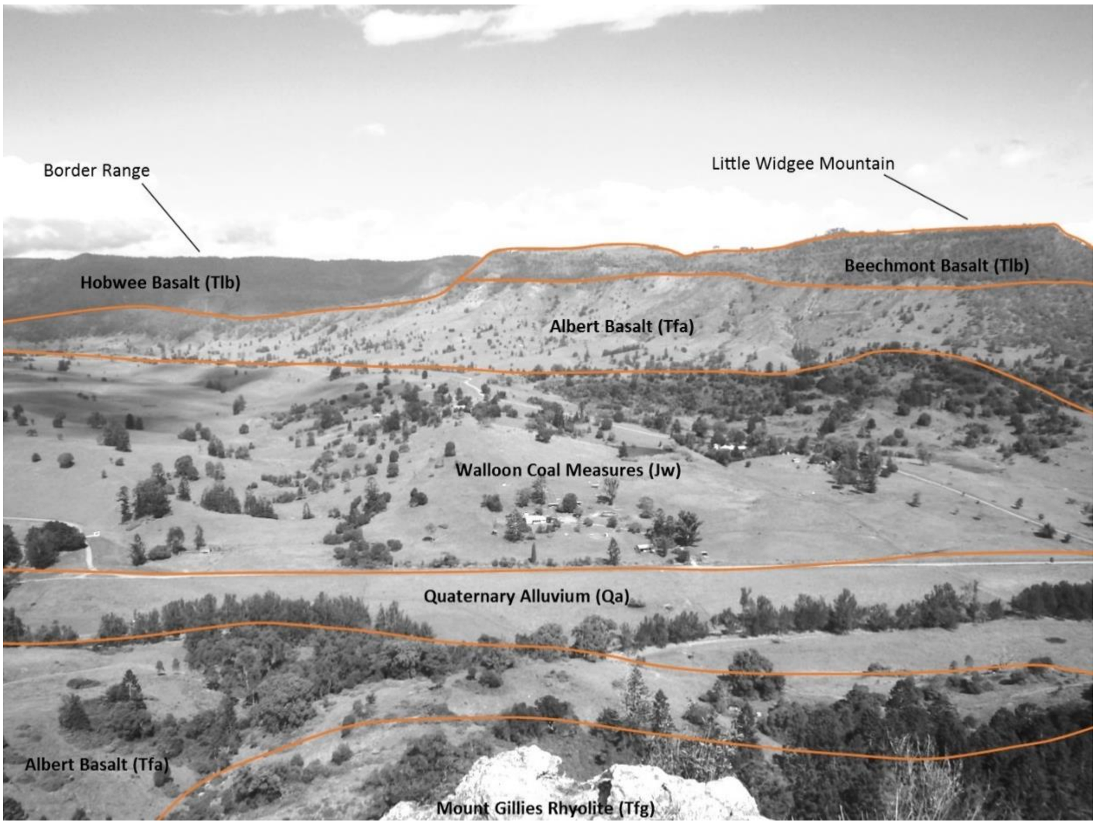


Figure 17. Geology of the upper Albert River. Looking south-west from site 2056 to Little Widgee Mountain and the Border Range.

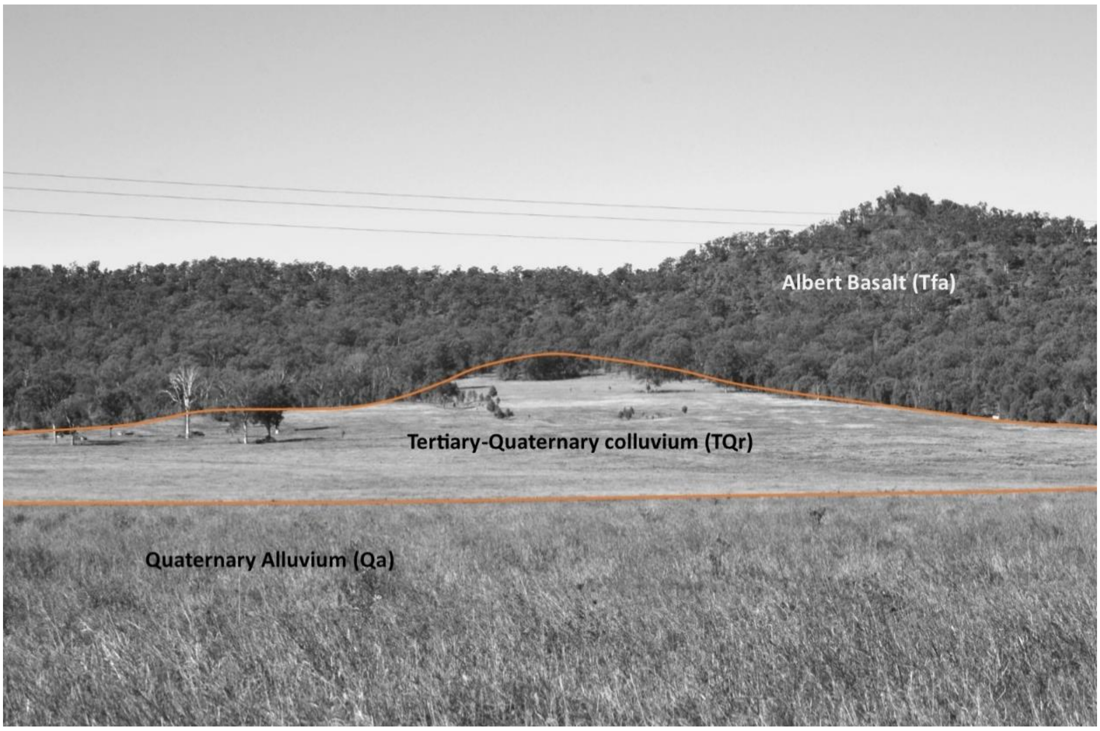


Figure 18. Basalt and basalt derived geologies at Tabragalba (Site 2147 looking east).

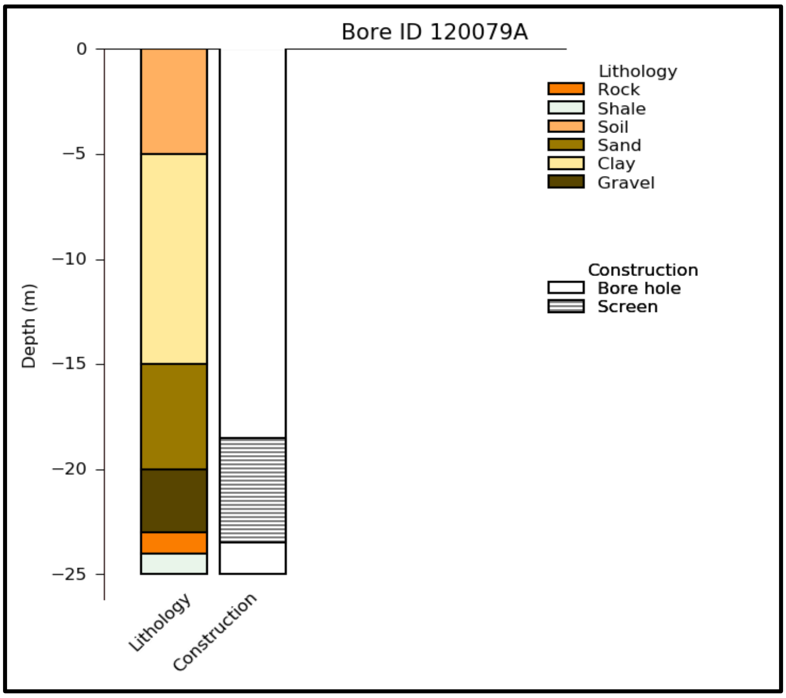


Figure 19. Typical groundwater bore log in Logan River alluvium at Tamrookum.

7. Vegetation

Since the commencement of European colonisation in the early 1840's, the vegetation in the project area has been extensively modified through a combination of timber harvesting, grazing, agriculture and urban development. The alluvial plains have been extensively cleared for grazing, pasture production and irrigated cropping. The lower to mid slopes in most areas have also been extensively cleared for grazing on native pastures, or in higher rainfall areas, grazing on introduced kikuyu grass *(Cenchrus clandestinum).* Generally, regrowth and remnant native vegetation are more prevalent on the steeper slopes and hilltops where access is limited and conditions are unsuitable for grazing. It was reported in 2015 that less than 30% of remnant vegetation communities remain in the Scenic Rim Regional Council area (Scenic Rim Regional Council 2015).

7.1. Vegetation on the Triassic-Jurassic Sediments

To the west of the Logan River flats, undulating hills and rises, grading to steep and very steep hills are composed of predominately sedimentary rocks of the Marburg Group (Koukandowie Formation (Jbmk) and Gatton Sandstone (Jbmg)) supporting mixed open eucalyptus forests. The RE descriptor for the most extensive plant community is 12.9-10.2 - *Corymbia citriodora* subsp. *variegata* (spotted gum) open forest or woodland usually with *Eucalyptus crebra* (narrow-leaved ironbark) (Figure 21).

Figure 20. *Corymbia citriodora* subsp. variegata woodland (RE 12.11.5) (Site 795).

Figure 21. ***Corymbia citriodora*** **open forest (RE 12.9-10.2) (Site 2021).**

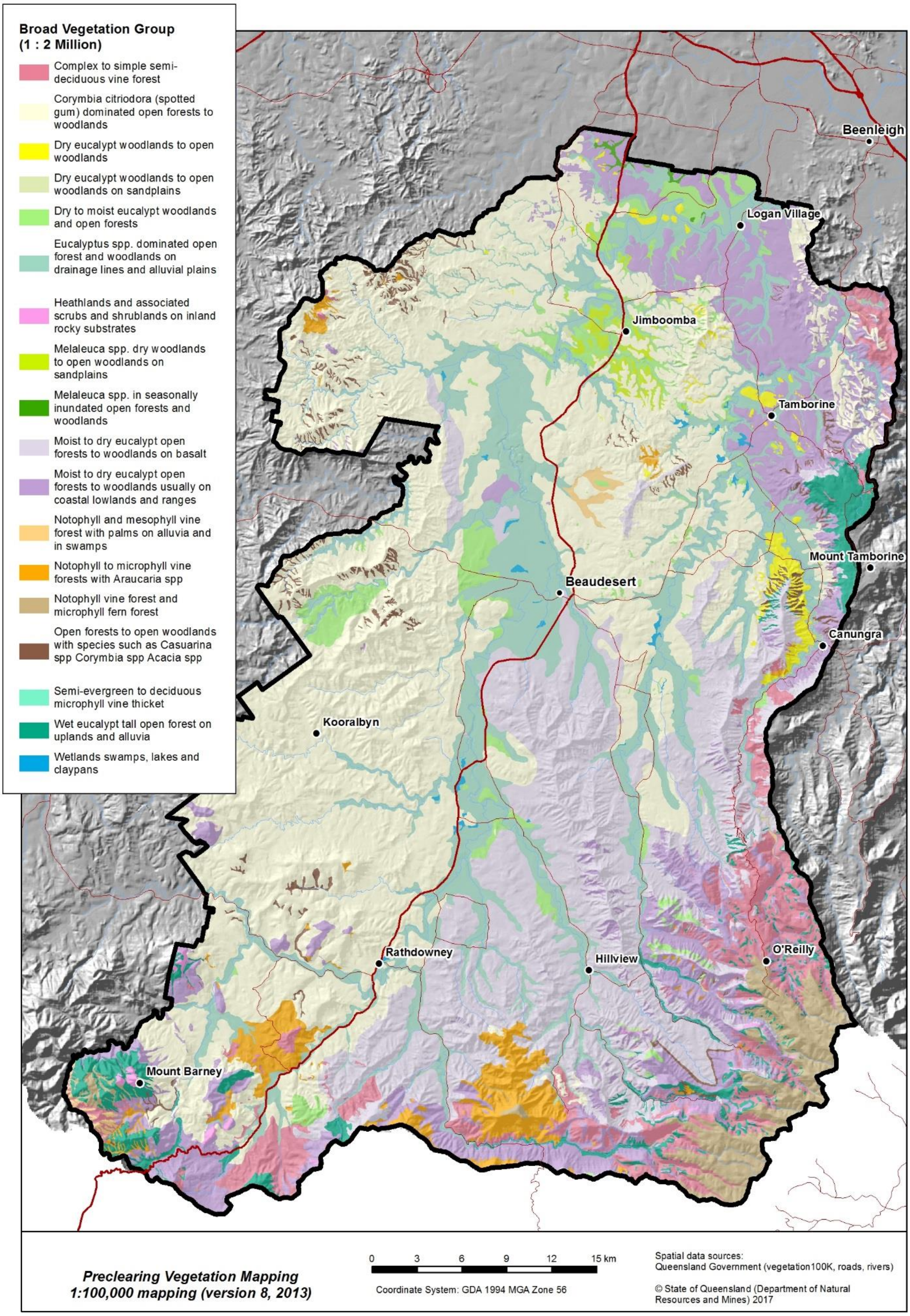


Figure 22. Pre-clearing vegetation mapping for LARA project area.

Three other less common woodland types are also found within this landscape sharing many of the same component species but with different species assuming dominance as follows:

- *E. crebra +/- E. tereticornis* (Queensland blue gum), *Corymbia tessellaris* (Moreton Bay ash), *Angophora leiocarpa* (smooth barked apple), *E. melanophloia* (silver leaved ironbark) woodland (RE 12.9-10.7)
- *Eucalyptus moluccana* (gum-topped box) open forest (RE 12.9-10.3) and *Lophostemon confertus* (brush box) or *L. suaveolens* (swamp mahogany) dominated open forest usually with emergent eucalyptus and/or corymbia species, occurring in gullies and southern slopes (RE 12.9-10.17a).

East of the Logan River and to the north of Beaudesert, the Jurassic sediments outcrop in a different configuration with the Walloon Coal Measures, Koukandowie Formation, and Gatton Sandstone presenting from west to east. The Walloon Coal Measures form undulating low hills and the Koukandowie Formation and Gatton Sandstone hills and rises in these locations are generally lower and less steep than those west of the Logan River. These landscapes have been extensively cleared for agriculture with remnant vegetation mainly confined to steep hillslopes and crests. Gully erosion is widespread and damage to road infrastructure was also observed.

The resulting vegetation pattern differs slightly from that to the west of the Logan floodplains with *Corymbia citriodora* subsp. *variegata* open forest or woodland, usually with *Eucalyptus crebra*, (RE 12.9-10.2) still being the most extensive plant community. *Eucalyptus moluccana* (gum topped box) open forest (RE 12.9-10.3) and *Eucalyptus crebra* +/- *E. tereticornis*, *Corymbia tessellaris*, *Angophora leiocarpa*, *E. melanophloia* woodland (RE 12.9-10.7), also occur.

Figure 23. Remnant *A. cunninghamii* on Walloon Coal Measures (RE 12.9-10.16) (Site 374).

In the south-west corner of the study area, between Palen Creek and the Logan River, an outcrop of the Walloon Coal Measures forms a distinctive undulating landscape supporting traces of the former *Araucaria microphyll* to notophyll vine forest, (RE 12.9-10.16) evident in patches of regrowth

Araucaria cunninghamii (Figure 23). An outcrop of the same geology between the headwaters of Widgee Creek and the Albert River (right branch) exhibits similar vegetation remnants.

7.2. Vegetation on the Neogene Volcanics

To the east of the Logan River and south of Beaudesert towards the steep hills of the McPherson range, the hills of the Albert Basalt group have been extensively cleared. Gully erosion and landslips are an obvious feature of the landscape (Resilient Rivers Initiative 2017).

The dominant vegetation is a mixed eucalyptus woodland to open forest now occurring mainly on the steeper slopes. The two dominant vegetation communities are *E. crebra +/- E. melliodora, E. tereticornis* woodland (RE 12.8.16) (Figure 24) and *Eucalyptus eugenioides* (thin-leaved stringy bark), *E. biturbinata* (grey gum), *E. melliodora +/- E. tereticornis, Corymbia intermedia* woodland (RE 12.8.14). A variation of this regional ecosystem, *Eucalyptus moluccana* open forest (RE 12.8.14a) was noted at a number of sites including Site 706 (Figure 26).

Figure 24. *Eucalyptus crebra* woodland (RE 12.8.16) (Site 2113).

On the stony summits of low basalt hills near Echo Hills Road at Laravale (Site 2051) the endangered RE12.8.24 (*Corymbia citriodora* (spotted gum) open forest) was observed. This plant community is also found in small areas on lower slopes near Mt Barney, Mt Gillies and Mt Chinghee.

Distributed throughout these extensive areas of eucalyptus woodlands and open forests, small patches of complex notophyll vine forest with scattered *Araucaria cunninghamii* (RE 12.8.4) occur on slopes and gullies where conditions are more moist and sheltered (Figure 25). Larger remnants of this RE were also observed on the slopes of Mt Chinghee and on the upper slopes towards the NSW border in the Running Creek, Christmas Creek and Albert River valleys.

On the south and south-east margin of the study area, the steep hills and mountains of the McPherson Range and the Lamington Plateau rise to over 1000 m altitude and experience rainfall in excess of 1000 mm per annum. The headwaters of the Albert River, and those of Christmas Creek and Running Creek on the Logan system, cut deep, steep sided valleys into the basalt ranges. The combination of high rainfall, fertile soils and diverse landforms has resulted in the high level of biodiversity recognised by the World Heritage Listing of the National Parks in the region as part of the Gondwana Rainforests of Australia (Office of Environment and Heritage 2018).

The Hobwee Basalt (Tlh) of the Lamington Plateau and the top of Mount Chinghee, above about 600 m, support dense rainforest vegetation classified as complex notophyll vine forest and microphyll fern forest on high peaks and plateaus (RE 12.8.5). This forest type provides habitat for endemic and threatened plant species at the northern limit of cool subtropical climate conditions. Also found above about 600m, mainly on the steep slopes below the Lamington Plateau and McPherson range, on the Beechmont and Albert basalts, is the complex notophyll vine forest (RE 12.8.3). Both these regional ecosystems are well represented in national parks.

Figure 25. Regrowth *A. cunninghamii* vine forest (RE 12.8.4) in foreground. Site 2055 to Mt Razorback.

The steep slopes of the headwater valleys below 600 m have been cleared for grazing in many places, however, the following regional ecosystems were evident either individually or in combination:

- Complex notophyll vine forest with *Araucaria cunninghamii* (RE 12.8.4) (Figure 25)
- *Eucalyptus eugenioides, E. biturbinata, E. melliodora +/- E. tereticornis, Corymbia intermedia woodland*, (RE 12.8.14) and
- Araucaria complex microphyll vine forest containing *Araucaria cunninghamii* (RE 12.8.13).
-

Figure 26. *Eucalyptus moluccana/E. crebra* open forest with *Xanthorrhoea johnsonii* (RE 12.8.14a) (Site 706).

7.3. Vegetation of the Mount Barney region

7.3.1. Igneous rocks

The elevated peaks and slopes, including Mt Barney, Mt Ernest, Mt Lindsay, Mt Gillies and Mt Maroon, support a broad range of vegetation communities in response to differing altitude, soil morphology, slope, aspect and precipitation.

On the peaks and higher slopes of Mt Barney, Mt Maroon, Mt Ernest, Mt Gillies and Campbells Folly where rhyolite or other igneous outcrops form stone pavements or shallow rocky soils, a heath of scattered shrubs or open woodland is found (RE 12.8.19). On the steep exposed slopes this plant community is often found combined with *Eucalyptus racemosa* subsp. *racemosa* (scribbly gum) low shrubby woodland to open woodland (RE 12.8.20).

In high rainfall areas at elevations above 600 m, where there is adequate soil, *E. campanulata* tall open forest is dominant (RE 12.8.1). Suitable conditions for this plant community are found on the upper slopes of Mt Barney, Mt Maroon and Mt Ernest.

Also found on southern slopes, above 600 m in the Mt Barney and Mt Lindesay areas are patches of complex notophyll vine forest (RE 12.8 5). These cool subtropical rainforests are here at the northern limits of their climatic range.

Below 600 m, the hillslopes exhibit open forests with a range of dominant tree species including *L. confertus* (brush box) open forest (RE 12.8.9) found on Mt Gillies, and *E. saligna* (Sydney blue gum) or *E. grandis* (flooded/rose gum) tall open forest seen at Mt Lindesay. (RE 12.8.8) (Figure 27). Open forests dominated by *E. acmenoides* (12.8.25) and *E. eugenioides* (12.8.14) also occur. On lower slopes of Mt Gillies and towards Campbells Folly, an open forest woodland of *Corymbia citriodora* subsp. *variegata*, *Eucalyptus crebra* +/- *E. moluccana* is found (RE 12.8.24).

Figure 27. ***Eucalyptus saligna subsp. salignalE. grandis* tall open forest (RE 12.8.8) (Site 304)**

7.3.2. Uplifted/metamorphic and sedimentary formations of the Mt Barney Beds.

Below the steep granophyre outcrop that forms the distinctive peak of Mt Barney, the steeply inclined Carboniferous meta-sediments and sediments circling the volcanic peak are known as the Mount Barney Beds (Cy).

To the east of Mt Barney, the exposed Carboniferous rocks of the Mount Barney Beds form steep to rolling hills which support *Corymbia citriodora* subsp. *variegata*, *Eucalyptus crebra* woodland (RE 12.11.6) (Figure 28). Steep sheltered gullies in this area support an open forest of *Eucalyptus siderophloia, E. propinqua +/- E. microcorys, Lophostemon confertus, Corymbia intermedia, E. acmenoides* (RE 12.11.3).

The Carboniferous formations on the more sheltered southern flank of Mt Barney support a notophyll vine forest +/- *Araucaria cunninghamii* (RE 12.11.10) with distinctive pockets of simple notophyll vine forest often with abundant *Archontophoenix cunninghamiana* (bangalow palm) in the more sheltered gullies (RE 12.11.1).

Figure 28. *Corymbia citriodora subsp. variegata* and *Eucalyptus crebra* woodland (RE 12.11.6) on the Mount Barney Beds (Site 295)

7.3.3. Jurassic sediments of the Marburg Formation

On the lower slopes of Mount Barney, below the Mount Barney Beds the sediments of the Marburg Formation have also been exposed through the up-thrusting of the Mt Barney granophyre. The more exposed sites support an open forest made up of *Eucalyptus acmenoides*, *E. propinqua, Corymbia intermedia* +/- *E. microcorys, Lophostemon confertus* open forest (RE 12.9-10.17e). The steep sheltered gullies provide conditions for microphyll to notophyll vine forest +/- *Araucaria cunninghamii* (RE 12.9-10.16).

On the lower slopes to the south-east, on the Marburg Formation, the *Corymbia citriodora subsp. Variegata* +/- *Eucalyptus crebra* open forest or woodland continues (here with the RE code 12.9-10.2 because it occurs on the sediments of the Marburg Formation).

7.4. Vegetation on the Quaternary alluvium of the flood plains

The flat to gently undulating alluvial plains, levees and terraces of the Logan and Albert Rivers and their tributaries show traces of the former dominant vegetation of *Eucalyptus tereticornis* (Queensland blue gum) woodland. Remnants of this regional ecosystem (RE 12.3.3) constitute less than 10% of the former extent state-wide. Small areas of this RE were observed on private lands (Figure 29) and there is a protected population in Mount Barney National Park.

Conspicuous old growth Queensland blue gums still form a distinctive component of the regional landscape with large individual trees scattered across grazing and cropping lands on alluvial flats. The hollows formed in large older trees provide significant shelter and breeding sites for a range of fauna species (Smith & Hogan 2013) (Figure 30).

Figure 29. *E. tereticornis* woodland (RE 12.3.3) fringing palustrine wetland (RE 12.3.8) (Site 2030)

Figure 30. Little corellas (*Cacatua sanguinea*) using a mature *E. tereticornis* hollow

Mapping of pre-clearing vegetation communities (Figure 23) indicates that *E tereticornis* woodland was commonly associated with *Eucalyptus grandis* tall open forest (RE 12.3.2) and *Eucalyptus tereticornis, Casuarina cunninghamiana subsp. cunninghamiana* +/- *Melaleuca* spp. fringing woodland (RE 12.3.7).

Remnants of *E. grandis* tall open forest on alluvial plains (RE 12.3.2) were observed in the steep narrow valleys at the headwaters of the Logan River, Palen Creek, Running Creek and Christmas

Creek. The *E tereticornis, C cunninghamiana* +/- *Melaleuca* spp. fringing woodland (RE 12.3.7) was observed in scattered patches throughout the study area.

Field observations of riparian areas are consistent with the findings of the Healthy Land and Water report cards for 2017 for the Albert and Logan Rivers catchment, which note that riparian vegetation extent remains poor, with about 30% of streambanks having no vegetation other than ground cover (Healthy Land and Water 2017).

8. Methodology

8.1. Survey type

The form of this soil survey generally follows the *free survey* methodology as described by Hewitt *et al.* (2008) with planning, research, mapping, reporting and validation phases. Describing soils and landscapes using transects oriented at 90 degrees to the contour was the preferred method where terrain allowed.

8.2. Project planning

The soils and landscapes of the Logan and Albert Rivers catchment were identified as a critical data gap in the foundational land resource data set for South-East Queensland. Project work commenced with a desktop review of existing data including; existing soils sites, adjacent land resource assessments and mapping, and the geology of the region. Key stakeholders including South-East Queensland Catchments Regional Body for NRM (now Healthy Land and Water) and Scenic Rim Regional Council were consulted and key landowners contacted.

8.3. Field work

Field work commenced with a reconnaissance tour of the project area to familiarise staff with the region, meet key stakeholders, fine-tune site selection, and assess the quality of existing site data. Effort was focused on characterising the agriculturally important alluvial floodplains and lower to mid slopes at a scale of 1:50 000 using traditional soil survey techniques. More rugged and inaccessible areas were given less attention and were mapped at broader scales (1:100 000 and above) (Figure 31).

Field descriptions were guided by the terminology and codes of the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain 2009). Soil morphology descriptions were undertaken at each site noting texture, colour, mottles, structure, segregations, coarse fragments, field pH, permeability and drainage. Site analysis included location, slope, landform element, landform pattern, surface condition, erosion, geology, lithology and vegetation (where present).

Soil cores for each site were extracted using a hydraulic push tube mounted on a four wheel drive vehicle (Figure 32). Relatively undisturbed soil cores of 50 mm diameter and a maximum depth of 1800 mm were produced for full field description at 809 sites.

272 observation sites of lesser detail were also visited, where a full site description was not necessary, to inform mapping. These sites typically included field measurements of depth, colour, lithology, landform element, geology/lithology and vegetation.

Additionally, sites from other projects which overlapped this one were used to inform mapping and develop soil profile classes (SPCs) (Appendix 1). These included the South-East Queensland (SEQ) project (covering the Logan City Council and lower Albert River portions of this study) and Moreton Field Manual (MFM) project among others. This yielded a further 415 sites.

Dominant vegetation species were recorded for all sites where apparent, and sightings have been checked for alignment with the Regional Ecosystem Description Database (REDD).

In total, the mapping for this project is derived from 1496 field observations.

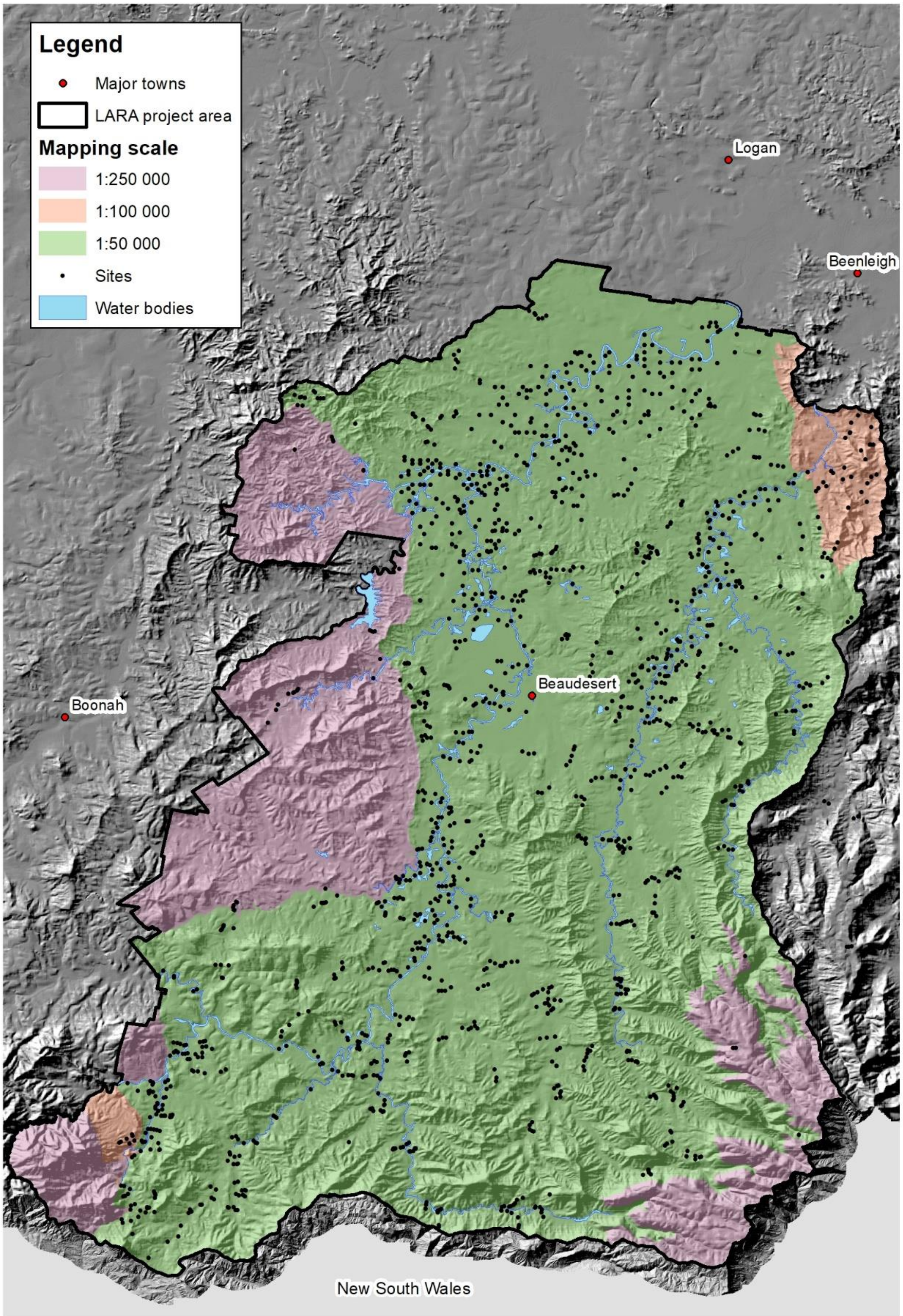


Figure 31. LARA project site locations and mapping scales

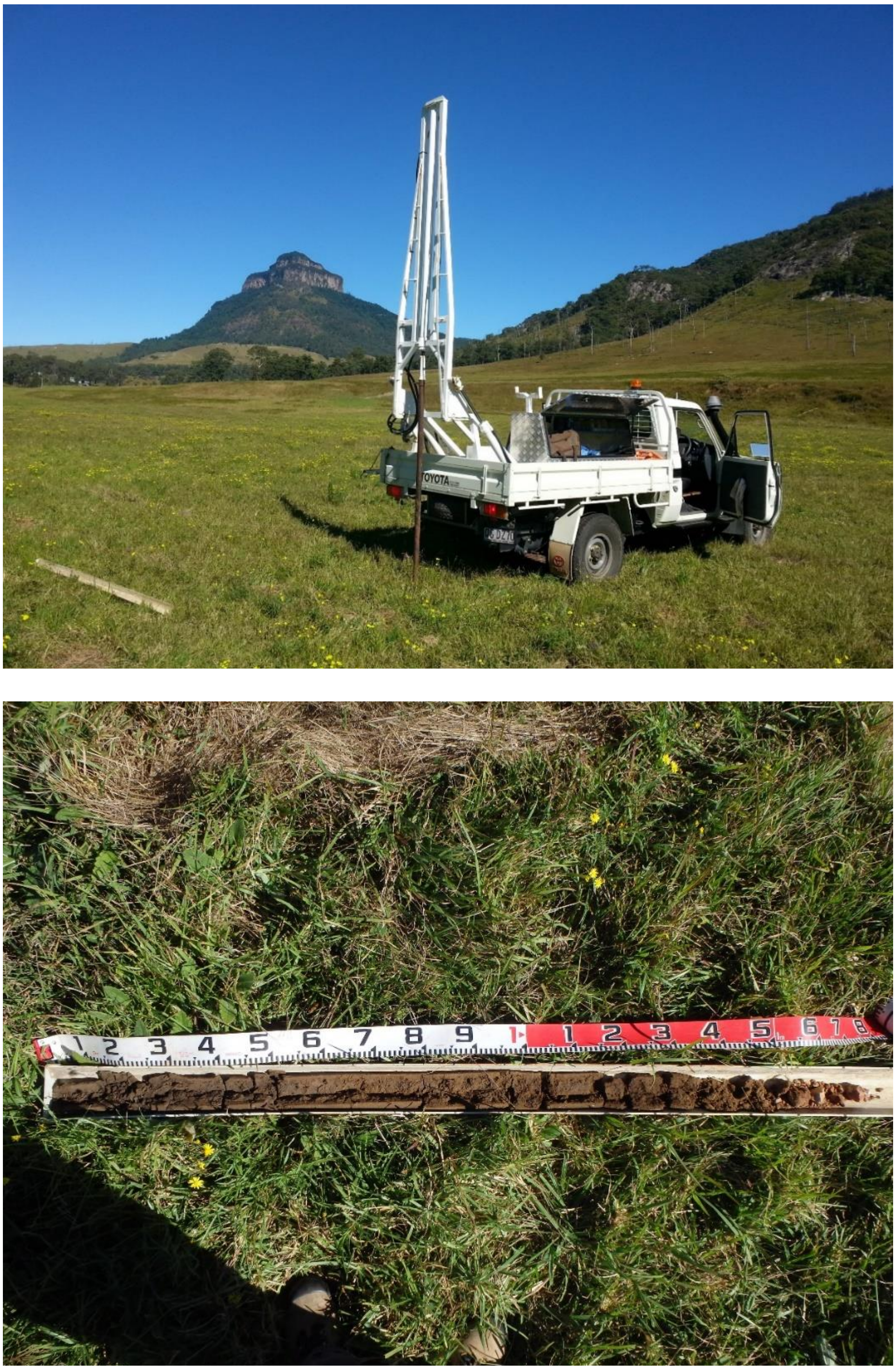


Figure 32. Soil coring rig and resultant soil core near Mt Lindsay (Site 280)

8.4. Unique mapping areas (UMAs)

Combining the field site and observation information with SPC, terrain and geology data enabled the production of 1485 unique mapping areas (UMAs), each with a unique combination of landform, geology and soil.

8.5. Soil analysis

A total of 19 soil profiles were sampled for laboratory analysis representing some of the major soil profile classes of the survey area. Of these only six were fully sampled and analysed while the remaining profiles were strategically sampled at three relevant depths.

Where possible and/or required, profiles were sampled to a depth of 1.5 m and analysed at standard intervals. Analysed depths were occasionally altered to allow for thin surface horizons or where standard depths would cross soil horizon boundaries (Baker & Eldershaw 1993).

Data from 11 previously analysed existing sites, was also considered by this project.

Chapter 11 and Appendix 3 contain the analysis results, their interpretation and the laboratory methods used. Further information on analytical interpretation and laboratory methods can be found in Baker and Eldershaw (1993) and Rayment and Lyons (2011).

8.6. Agricultural land suitability

Each UMA was assessed for its agricultural suitability against 16 limitations across a range of agricultural land use options and assigned an agricultural land class accordingly. A summary of the classes assigned and their areas is contained in Chapters 13 and 14, while details of the limitations, the agricultural suitability framework and the definitions of the agricultural land classes are contained in Appendix 4 and Appendix 5.

8.7. Data management and analysis

Soil profiles were classified using The Australian Soil Classification (Isbell and National Committee on Soil and Terrain 2016). The data was then entered into the Queensland Government's soil and land information (SALI) database (Biggs *et al.* 2000). Each site was assigned a Soil Profile Class (SPC) and where appropriate, soil phases and soil variants (McKenzie *et al.* 2008) were also described. The SPCs were arranged in conceptual form detailing; landform, geology, vegetation, permeability, drainage, surface features and soil profile morphology. A key was prepared and then refined for the identification of SPCs in the field (Appendix 2).

Site and soil chemical analysis data, aerial imagery interpretation, and a Light Detection and Ranging (LiDAR) derived Digital Elevation Model (DEM) were used to map the region into Unique Mapping Areas (UMAs). SPCs were then allocated to each UMA. LiDAR was also used to develop elevation and other digital terrain derivatives such as slope, Topographic Position Index (TPI), Multi-Resolution Valley Bottom Flatness (MRVBF) and Topographic Wetness Index (TWI) to assist with UMA derivation.

For further information on DEM derivatives which may be useful in land resource assessment refer to Smith & Crawford (2015) and McBratney *et al.* (2000 & 2003).

8.8. Mapping validation

A total of 82 additional sites described during 2019 were used to assess the accuracy of polygon mapping and attribution. The results of this validation are reported in Appendix 8.

9. Soils and landscapes

This chapter aims to describe both the soils present in this survey and the way they interact with their landscapes. Soils have been broadly grouped using their geology/geomorphology as the primary characteristic, with lithology and landforms used for further division.

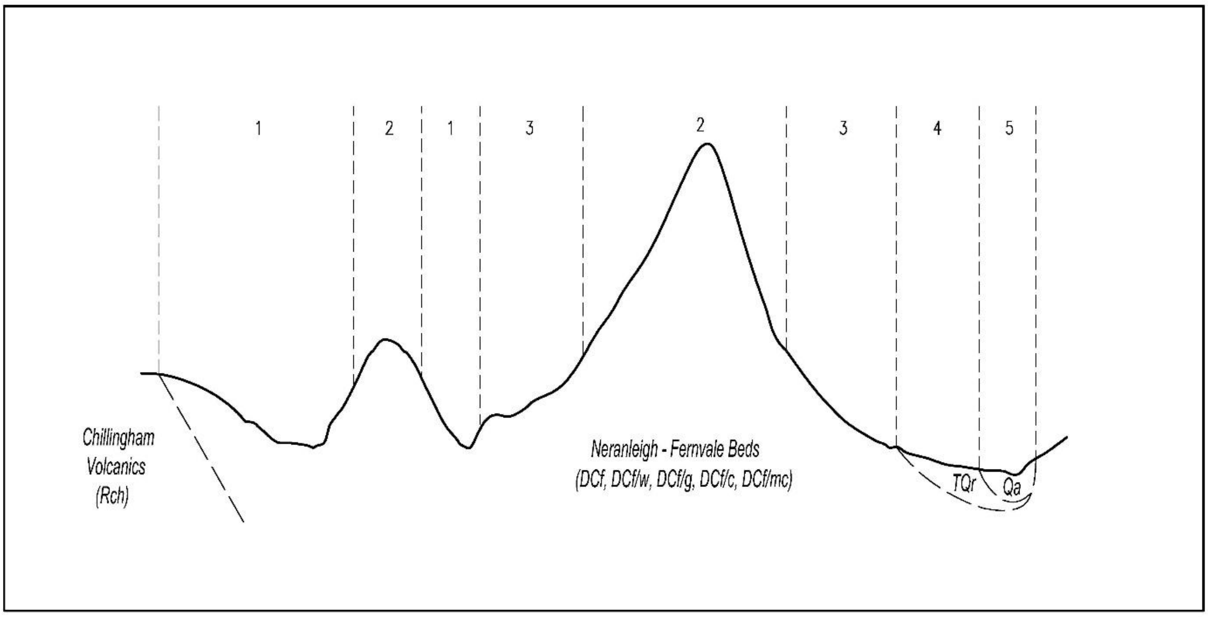
Landscapes and their associated soils are shown via a series of diagrammatic cross-sections representing the relationships between geological units, landforms and SPCs. These diagrams are derived from digital elevation model (DEM) cross-sections at the locations identified.

Names of SPC's are based on localities and natural features within the survey area, however, a number have been carried over from previous surveys, where all descriptors and parent materials match, and demonstrate the continuity of these SPC's between surveys. It is important to note that the use of a particular locality in an SPC name does not imply that it is the dominant soil at that locality, only that it was likely first identified in the vicinity. In the following discussion, SPC names are abbreviated and displayed in italics, e.g. *Barney* soil profile class is referred to as *Barney* soil or simply *Barney*.

A total of 93 soil profile classes, 9 variants and 5 phases are described here, these have been defined by Powell (2008). Shallow soils formed on the basalt hills (*Cainbable, Sarabah* and *Wonglepong*) occupy the largest part of the project area (37 353 ha) followed by the shallow sandstone derived soils (*Mundoolun, Woollaman* and *Cedar Vale*) in the western and northern portions of the project (23 000 ha). *Bell (SEQ)* is by far the most common alluvial soil (8617 ha) followed by *Bremer Buried Phase* (1975 ha). Appendix 1 contains the full SPC descriptions. Appendix 2 has an SPC key utilising geological, morphological and physio-chemical criteria for delineation.

9.1. Soils and landscapes of the Neranleigh-Fernvale Beds (DCf, DCf/c, DCf/g, DCf/mc, DCf/w)

Located in the north-east, the highly metamorphosed Devonian/Carboniferous period Neranleigh-Fernvale Beds form a relatively small portion of the study area to the east of the Albert River and continue beyond the study area to the east and north.



Unit	Landform	Soil Description	Soil Profile Class
1	Slopes of rises to hills. Various slopes to >40%.	Shallow to moderately deep, strongly acidic, gradational and texture contrast soils on arenite/sandstone, chert and greywacke. Slowly to moderately well drained.	***Corbould* (Cd)** (Grey/Brown Kandosol/Kurosol)
2	Hillcrests and slopes of low hills and hills. Slopes 5–>40%.	Very shallow to shallow, acidic to neutral, grey, black and brown, loamy to clay loamy soils over chert and sandstone/arenite from 0.1 m. Moderately well drained.	***Ferny* (Fy)** (Leptic/Bleached Leptic Tenosol)
3	Lower, mid and upper slopes of low hills and hills. Slopes 10–>>30%.	Shallow to deep, acidic to neutral, red and brown gradational or uniformly fine soils over greenstone, mudstone, chert, arenite, conglomerate or sandstone. Soils are occasionally bleached and/or mottled. Moderately well drained.	***Neranleigh* (Nr)** (Brown/Red Dermosol) ***Neranleigh Shallow Phase* (NrSp)** (Black Dermosol)
4	Lower slopes and fans of low hills and hills. Slopes 1–15%.	Deep to very deep, black, frequently mottled, uniformly fine soils formed on colluvium. Neutral to alkaline and may be saline, rarely calcic. Imperfectly drained.	***Shaws* (Sh)** (Black/Brown Dermosol)
5	Plains, terrace plains, levees, fans and flats. Slopes 0-10%.	Deep to very deep, uniformly fine textured, non-cracking, black, brown and grey soils or sodic texture contrast soils. Subsoils are neutral to alkaline, non-calcic, frequently mottled, slightly saline and/or vertic. Buried horizons are not encountered within 1.8 m. Poorly to moderately well drained.	***Bremer* (B)** (Brown/Black/Grey Dermosol) ***Spencer* (Sp)** (Grey/Brown Sodosol)

Figure 33. *Corbould* and *Ferny* soil examples. Top row – *Corbould* soil profile exposure (Site 793) and *Ferny* soil core (Site 796); Bottom row – *Neranleigh* soil core (Site 794) and undulating to rolling hills rising to steep hills (background) on Neranleigh-Fernvale Beds.

Table 3. SPC's summarised by geological groups and major characteristics

	Uniform coarse to medium soils	Texture contrast soils	Gradational soils	Very shallow to moderately deep uniformly fine non-cracking soils (<1.0m)	Deep to very deep uniformly fine non-cracking soils (>1.0m)	Very shallow to moderately deep uniformly fine cracking soils (<1.0m)	Deep to very deep uniformly fine cracking soils (>1.0m)
Basalt dominated alluvium (Qa, Qpa, Qha)							*-Bell (SEQ)* *-Blenheim*[#]
Sedimentary dominated alluvium (Qa, Qpa, Qha)	*-Cressbrook* *-Jimboomba* *-Robinson* *-Logan*	*-Sippel* *-Spencer*[*] *-Cookes* *-Kilmoylar* *-Beausang*					*-Basel* *-Bridge*[^] *-Duggua* *-Waterford*[^]
Mixed source alluvium (Qa, Qpa, Qha)		*-Maclean*[^] *-Grigor*	*-Lockyer* *-Monsildale* *-Bromelton*		*-Bremer* *-Bremer Buried Phase* *-Hooper* *-Lockrose* *-Maroon*[^]		*-Cooeeimbardi*[#] *-Payne*[#^]
Mafic colluvium (Qr, TQr)				*-Wonglepong*	*-Palen*	*-Wonglepong*	*-Glenapp*
Siliceous colluvium (Qr, TQr)				*-Ernest*	*-Ernest*		
Siltstone colluvium (Qr, TQr)					*-Shaws*		
Mafic volcanic rocks (Tfa, Tlb, Tlh, Tid, Tv)	*-Sarabah Tenosol Variant*[S]			*-Cainbable*[S] *-Sarabah*[S] *-Tartar Shallow Phase* *-Telemon* *-Wonglepong*	*-Tartar* *-Tamborine*	*-Gorman*[S] *-Chinghee*	*-Chinghee* *-Glenapp*[#] *-Lindesay*[#] *-Palen*
Tertiary sediments (Ts)		*-Dunsinane* *-Brabazon Acidic Phase*[^]					
Beaudesert beds (Te/1, Te/2, Te/3, Td>Te/1, Td>Te/3)	*-Woollaman*	*-Brennan* *-Drynan* *-Drynan Alkaline Phase* *-Laravale* *-Saville*[*]		*-Josephville* *-Nindooinbah*	*-Nindooinbah Deep Phase* *-Nindooinbah Acidic Phase*[^]		*-Kagaru* *-Gould*[^]
Siliceous to intermediate volcanic rocks (Rch, Tfg, Tbsr, Tbgr)	*-Barney*[S^]		*-Ernest* *-Philp*		*-Ernest* *-Philp*		

Fine grained sedimentary rocks (Jw) **Fine grained sedimentary rocks (Jw) continued**	*-Woollaman*	*-Brennan* *-Drynan* *-Drynan Deep/Alkaline Variant* *-Brabazon* *-Brabazon Acidic Phase*[^] *-Edendale* *-Edendale Acidic Phase*[^] *-Josephville* *-Laravale* *-Lillydale* *-Lillydale Acidic Phase*[^] *-Nindooinbah* *-Nindooinbah Acidic Phase*[^] *-Saville*[*]	*-Edendale* *-Edendale Acidic Phase*[^] *-Lillydale* *-Lillydale Acidic Phase*[^] *-Nindooinbah* *-Nindooinbah Acidic Phase*[^] *-Josephville*	*-Edendale* *-Edendale Acidic Phase*[^] *-Lillydale* *-Lillydale Acidic Phase*[^] *-Nindooinbah* *-Nindooinbah Acidic Phase*[^] *-Josephville*	*-Nindooinbah Deep Phase* *-Nindooinbah Acidic Phase*[^] *-Edendale* *-Lillydale* *-Lillydale Acidic Phase*[^]		*-Kagaru* *-Gould*[^]
Medium to coarse grained sedimentary rocks (Ri, RJbw, Jbm, Jbmh, Jbmg, Jbmk)	*-Woollaman*[S] *-Yarrabilba*[S]	*-Birnam* *-Cedar Vale*[S] *-Clutha* *-Clutha Deep Variant* *-Flanagan*[^] *-Hardgrave* *-Koukandowie*[*] *-Knapp* *-Knapp Acidic Phase*[^] *-Kooralbyn* *-Kooralbyn Deep Phase* *-Lowood*[*] *-Mundoolun*[S] *-Pine Vale* *-Rathdowney* *-Stockleigh*	*-Cedar Vale* *-Dulbolla* *-Dulbolla Sodic Phase*[*] *-Flanagan*	*-Glenoake*	*-Flanagan* *-Dulbolla* *-Dulbolla Sodic Phase*[*] *-Richards*		*-Kagaru* *-Gould*[^]
Carboniferous sediments (Cy)	*-Ferny*[S]	*-Clutha*					
Metamorphic rocks and metasediments (DCf, DCf(x))	*-Ferny*[S] *-Neranleigh Shallow Phase*[S]	*-Corbould*[S^]	*-Neranleigh*	*-Neranleigh*	*-Neranleigh*		

[#]Self-mulching; [*]Sodic; [^]Strongly acid; [S]Very shallow to shallow

The Neranleigh-Fernvale landscape is dominated by mostly inaccessible and rugged undulating to steep low hills and hills consisting of resistant greywacke, chert and arenite in a complex combination with softer mudstone and greenstone. This landscape offers a wide range of soils from shallow, undeveloped Tenosols (*Ferny*) on crests and steep slopes to deep well developed Dermosols (*Shaws*) in fans. Steep sided valleys are punctuated by short lower slopes and foot slopes and incised, very narrow bands of alluvium (*Bremer/Spencer*) of limited agricultural potential.

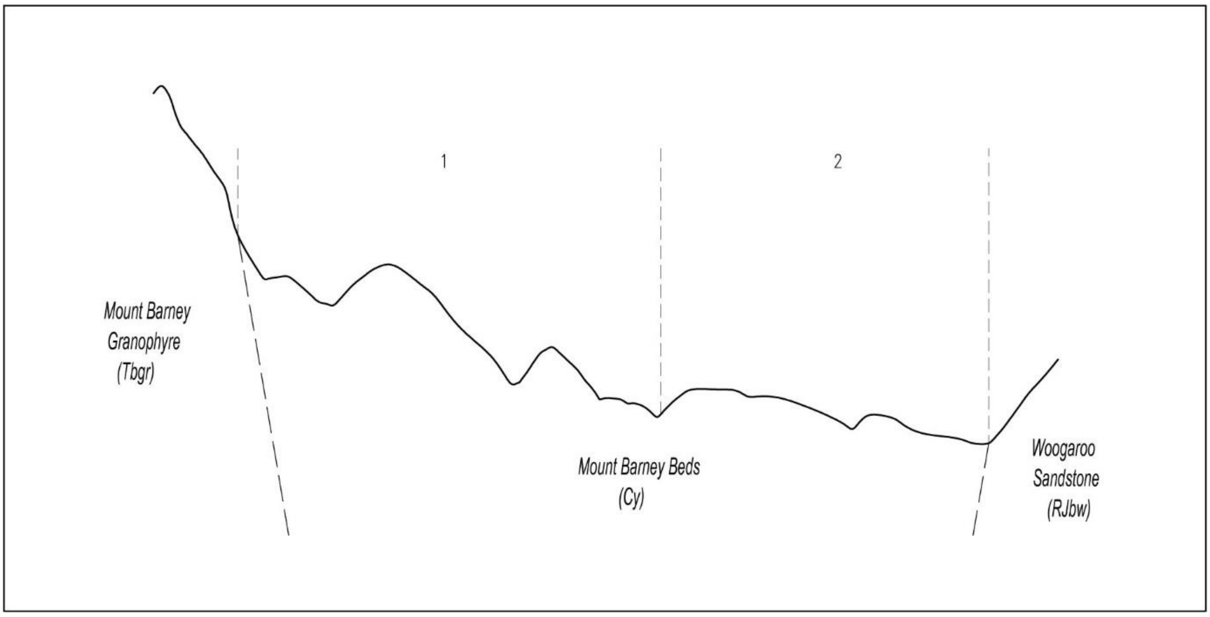
Soils in these landscapes, while cleared and farmed in the past, offer little agricultural potential beyond small areas for horticultural development on flats and gentle slopes and grazing of accessible slopes, largely due to topography, shallow soil depth and erosion risk. Agricultural land classes range from A2 to D. Table 4 summarises the dominant land suitability limitations for the soils of these landscapes.

Table 4. Major limitations to agricultural suitability in Neranleigh-Fernvale landscapes

Soil Profile Class	Significant agricultural suitability limitations
Corbould (Cd)	Erosion, slope, soil water availability, soil depth, nutrient deficiency, nutrient toxicity, landscape complexity.
Ferny (Fy)	Erosion, slope, soil water availability, soil depth, nutrient deficiency, landscape complexity.
Neranleigh (Nr)	Erosion, slope, soil water availability, nutrient deficiency, rockiness, landscape complexity.
Neranleigh Shallow Phase (NrSp)	Erosion, slope, soil water availability, soil depth, nutrient deficiency, rockiness, landscape complexity.
Shaws (Sh)	Landscape complexity, soil adhesiveness.

9.2. Soils and landscapes of the Mount Barney Beds

Low, rolling, and often rugged, hills define this landscape formed on a mix of sandstone, siltstone, mudstone, conglomerate, acid volcanics and silicate rocks. Soils are confined to shallow Tenosols (*Ferny*) and texture contrast Chromosols and Kurosols (*Clutha*).



Unit	Landform	Soil Description	Soil Profile Class
1	Hillcrests and slopes of low hills. Slopes 5–>40%.	Very shallow to shallow, acidic to neutral, grey, black and brown, loamy to clay loamy soils over sandstone from 0.1 m. Slowly to moderately well drained.	***Ferny* (Fy)** (Leptic/Bleached Leptic Tenosol)
2	Slopes of low hills. Slopes 1–15%.	Moderately deep to deep strongly acidic to neutral, grey and yellow, mottled and frequently bleached, texture contrast soils formed on quartzose sandstone, siltstone or mudstone. Subsoils may be saline and/or occasionally sodic. Poorly to imperfectly drained.	***Clutha* (Cl)** (Grey/Yellow Chromosol or Kurosol)

Soils in these landscapes, while cleared and farmed in the past, offer little agricultural potential beyond small areas for horticultural development on flats and gentle slopes and grazing of accessible slopes.

Grazing is the highest order agricultural land use in these landscapes, where cleared, and more intensive land uses are not recommended. Major limitations to agricultural suitability in these areas include erosion risk, slope and landscape complexity as summarised in Table 5. Agricultural suitability ranges from class C1 to D.

Figure 34. *Ferny* and *Clutha* soil examples. Clockwise from top left – *Ferny* soil core (Site 295); moderately inclined low hills landscape (Site 295); lower slope landscape (Site 297) with Mount Barney and other minor peaks in distance; *Clutha* soil core (Site 297).

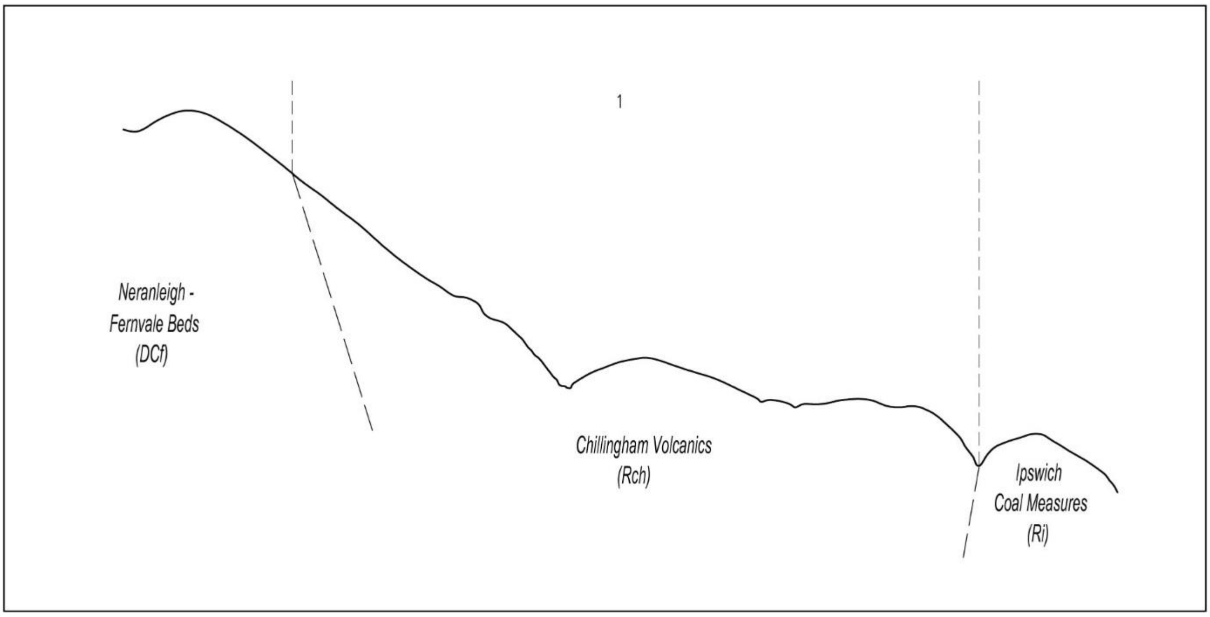
Table 5. Major limitations to agricultural suitability in Mount Barney Beds landscapes

Soil Profile Class	Significant agricultural suitability limitations
Ferny (Fy)	Erosion, slope, soil water availability, soil depth, nutrient deficiency, landscape complexity.
Clutha (Cl)	Erosion, slope, soil water availability, nutrient deficiency, landscape complexity.

9.3. Soils and landscapes of the Chillingham Volcanics (Rch, Rch/r, Rch/b)

Triassic period Chillingham Volcanics occupy an area of less than 200 hectares in the north-east of the study area adjacent to and west of the Neranleigh-Fernvale beds and overlying the Ipswich Coal Measures further west again.

These landscapes consist mostly of moderate to steep hills, however, they grade to rolling low hills in the north of the unit. A narrow range of soils has been mapped in this area made up of moderately deep Brown and Red Dermosols (*Philp*) on moderate and steeper slopes with imperfectly drained Grey Dermosols (*Ernest*) on gentler mid and lower slopes. The underlying lithology is rhyolite with occasional sandstone and shale.



Unit	Landform	Soil Description	Soil Profile Class
1	Slopes (rarely crests) of hills and low hills. Slopes 3–>30%.	Moderately deep to deep, brown, black or red, strongly acidic to neutral non-cracking clays on rhyolite. Moderately well to well drained.	***Philp* (Pp)** (Brown Dermosol, Red Dermosol)
	Mid and lower slopes and fans on rolling to steep low hills, hills and also mountains. Slopes 3-20%.	Moderately deep to deep, acidic to neutral, frequently bleached, grey gradational and uniformly fine soils. Subsoils are commonly mottled, slightly gravelly and may be alkaline at depth. Sandstone or rhyolite present from 0.9 m. Imperfectly drained.	***Ernest* (Er)** (Grey Dermosol)

Due largely to the topography of the unit, agricultural use is very limited and current uses include small area grazing (on some isolated and cleared lower slopes), forestry, national park and rural residential development. Agricultural suitability ranges from class C2 to D and major limitations are listed in Table 6.

Table 6. Major limitations to agricultural suitability in Chillingham Volcanics landscapes

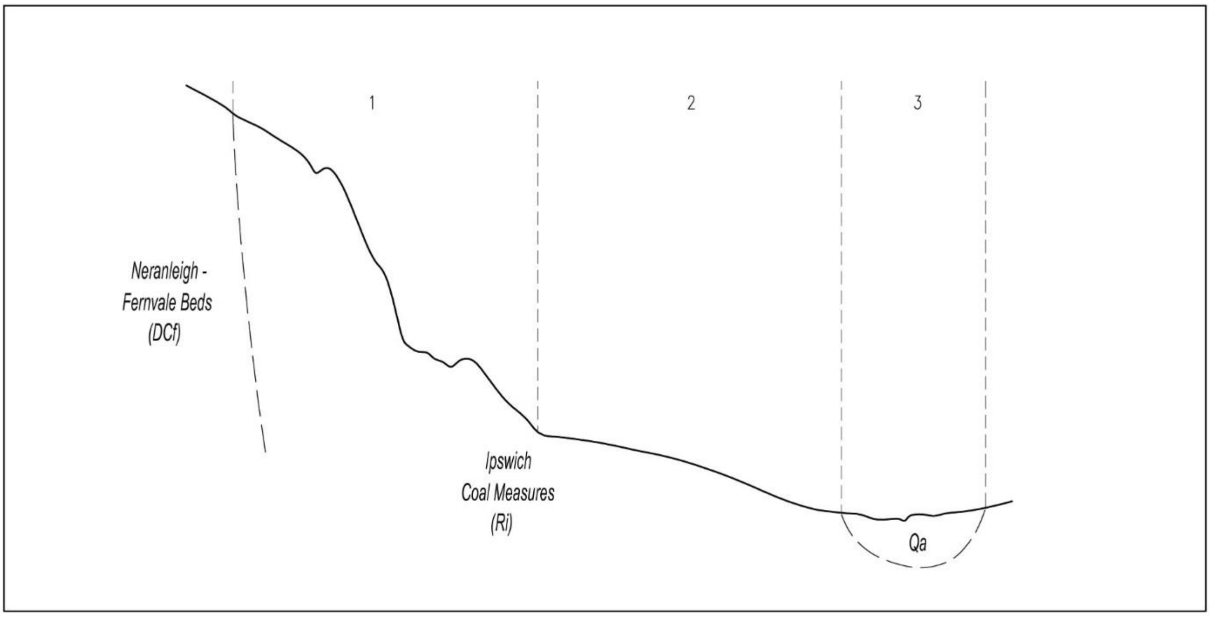
Soil Profile Class	Significant agricultural suitability limitations
Philp (Pp)	Erosion, slope, pH, soil depth, rockiness, landscape complexity.
Ernest (Er)	Erosion, slope, pH, soil depth, rockiness, landscape complexity.

Figure 35. Ipswich Coal Measures and Chillingham Volcanics landscape examples. Clockwise from top left – Ipswich Coal Measures, Chillingham Volcanics and Neranleigh-Fernvale landscape (Looking towards Site 236 & 239); Chillingham Volcanics exposure on Tamborine Mountain Road; rural residential development on Boomerang Road, Cedar Creek (images courtesy of Google Earth).

9.4. Soils and landscapes of the Ipswich Coal Measures (Ri)

Also located in the north-east section of the study area are the Ipswich Coal Measures, a Triassic period sedimentary formation of varying lithology including shale, conglomerate, coal, and siltstone. This landscape occupies more than 2000 hectares and overlies the Chillingham Volcanics to the east and is overlain by the Woogaroo Subgroup to the west.

Undulating to rolling rises and low hills, and occasionally steep hills, contacting low rises of Woogaroo Subgroup with similar soils or alluvium (*Cookes* soils) at their lower extent. Texture contrast soils occupy most of this landscape (*Kooralbyn* and *Clutha* soils) with some gradational soils found on lower slopes (*Clutha* soils).



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and slopes of undulating to rolling rises and low hills (rarely steep hills). Slope 2-30%.	Very shallow to moderately deep, strongly acidic to neutral, uniformly sandy to loamy soils with <15% clay, over sandstone from 0.2 m. Well drained.	***Yarrabilba* (Ya)** (Leptic/Bleached Leptic Tenosol, Brown/Grey Orthic Tenosol, Leptic Rudosol)
		Moderately deep to deep, frequently bleached, brown (rarely red) texture contrast soils. Subsoils are strongly acidic to neutral, frequently mottled and may be slightly to moderately saline or sodic. Imperfectly to moderately well drained.	***Kooralbyn* (Ko)** (Brown Chromosol or Kurosol, Red Chromosol or Kurosol)
2	Slopes of low hills. Slopes 1–15%.	Moderately deep to deep strongly acidic to neutral, grey and yellow, mottled and frequently bleached, texture contrast soils. Subsoils may be saline and/or occasionally sodic. Poorly to imperfectly drained.	***Clutha* (Cl)** (Grey/Yellow Chromosol or Kurosol, Grey Kandosol or Dermosol)
3	Plains on alluvial and flood plains.	Moderately to very deep texture contrast soils formed on sandstone and siltstone influenced alluvium. Frequently bleached clay loam over acidic, frequently mottled brown and grey clays. May be slightly sodic with slight to moderate salinity at depth. Imperfectly to moderately well drained.	***Cookes* (Co)** (Brown Chromosol, Brown Kurosol)

Agricultural suitability of these landscapes is class C2 to C3 and current land usage is non-agricultural. Major limitations to agricultural suitability are listed in Table 7.

Table 7. Major limitations to agricultural suitability in Mount Barney Beds landscapes

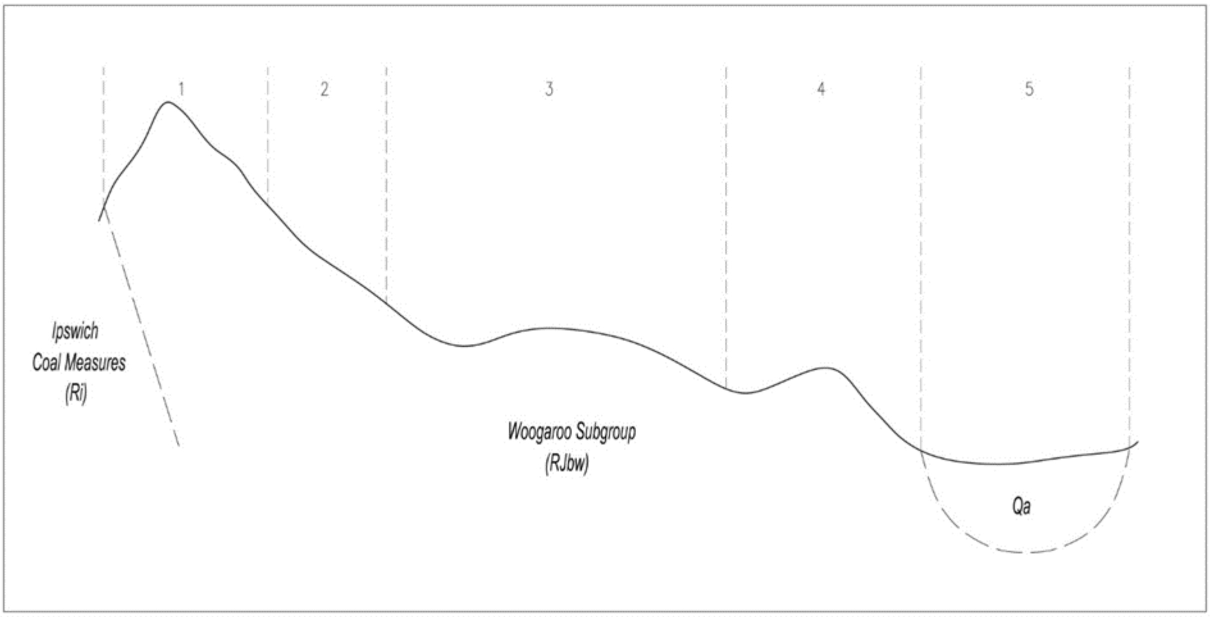
Soil Profile Class	Significant agricultural suitability limitations
Yarrabilba (Ya)	Erosion, slope, soil water availability, nutrient deficiency.
Kooralbyn (Ko)	Erosion, soil water availability, pH.
Clutha (Cl)	Erosion, soil water availability, nutrient deficiency.

9.5. Soils and landscapes of the Woogaroo Subgroup (RJbw/RJbwr)

The late Triassic to early Jurassic period sediments of the Woogaroo Subgroup cover some 14 250 hectares in the study area. The dominant lithology is quartzose sandstone, but siltstone, and shale were also identified. Minor members of this group (e.g. Ripley Road Sandstone and Aberdare Conglomerate) were not encountered.

9.5.1. Woogaroo Subgroup soil and landscape example 1:

Woogaroo Subgroup expressions are principally found in the north-east of the study area in a band running north-west to south-east from Park Ridge to Canungra where they overlie the Ipswich Coal Measures. They continue under the Gatton Sandstone to the west and are sometimes overlain by later alluvium.



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and slopes of undulating to rolling rises and low hills (rarely steep hills). Slope 2-30%.	Very shallow to moderately deep, strongly acidic to neutral, uniformly sandy to loamy soils with <15% clay, over sandstone from 0.2 m. Well drained.	***Yarrabilba* (Ya)** (Leptic/Bleached Leptic Tenosol, Brown/Grey Orthic Tenosol, Leptic Rudosol)
2	Slopes and crests on undulating to rolling rises and low hills. Slope up to 30%.	Moderately deep to deep, frequently bleached, brown (rarely red) texture contrast soils. Subsoils are strongly acidic to neutral, frequently mottled and may be slightly to moderately saline or sodic. Imperfectly to moderately well drained.	***Kooralbyn* (Ko)** (Brown Chromosol or Kurosol, Red Chromosol or Kurosol)
3	Hillslopes on undulating rises. Slope <5%.	Very deep, bleached, brown, mottled, strongly acidic texture contrast soils on sandstone. May be slightly to moderately saline. Imperfectly to moderately well drained.	***Kooralbyn Deep Phase* (KoDp)** (Brown Kurosol)

Unit	Landform	Soil Description	Soil Profile Class
4	Hillslopes, crests and ridges on undulating and rolling rises and low hills. Slope <25%.	Moderately deep to very deep, sodic, bleached, brown and yellow texture contrast soils on siltstone and sandstone. Subsoils are neutral to strongly alkaline, mottled, occasionally calcic and/or saline. Imperfectly drained.	***Koukandowie* (Kk)** (Brown Sodosol, Brown or Yellow Chromosol)
5	Plains, terrace plains and levees on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
		Deep to very deep, alkaline, black texture-contrast soils. Loamy to clay loamy surfaces over black clays. Subsoils may be calcic and/or vertic. Moderately well drained to well drained.	***Gunyah* (Gy)** (Black Chromosol)

The northern section of this band is characterised by undulating to rolling low hills and rises with the southern section also including some steeper rolling hills adjacent to Ipswich Coal Measures. Mostly, sandy *Yarrabilba* soils (Tenosols) are found on higher, steeper crests but Chromosols and Kurosols (*Kooralbyn*) may also be seen here. Slopes are dominated by red and brown Chromosols and Kurosols (*Kooralbyn*) but Sodosols and sodic Chromosol and Kurosols (*Koukandowie*) may also be present. Where slopes fall below 5% on rises, much deeper brown Kurosols form (*Kooralbyn Deep Phase*). Where slopes grade into more recent alluvium various soils are found from black and brown Chromosols to Vertosols (*Bell (SEQ), Cookes* & *Gunyah*).

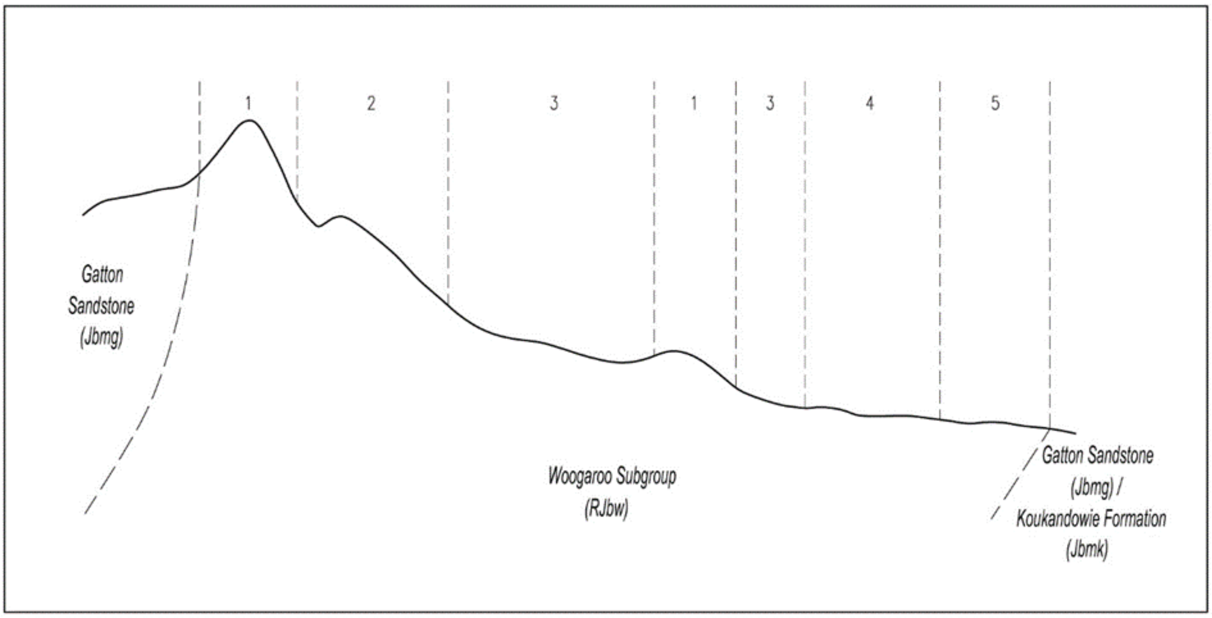
Current land uses include national park, residential and rural residential development and grazing. Large, future land development schemes such as the Yarrabilba Priority Development Area are located on these landscapes. Soils in these landscapes (with the exception of alluviums) are not well suited to more intensive forms of agriculture with agricultural land classes of C1 to C3. Major limitations to improved agricultural suitability are erosion risk, soil water availability and nutrient deficiency as listed in Table 8.

Table 8. Major limitations to agricultural suitability in Landscape 1 on Woogaroo Subgroup

Soil Profile Class	Significant agricultural suitability limitations
Yarrabilba (Ya)	Erosion, slope, soil depth, soil water availability, nutrient deficiency.
Kooralbyn (Ko)	Erosion, pH, soil water availability, nutrient deficiency.
Kooralbyn Deep Phase (KoDp)	Soil water availability, nutrient deficiency, pH, permeability, drainage.
Koukandowie (Kk)	Erosion, subsoil erosion, soil water availability, nutrient deficiency, permeability, drainage.

9.5.2. Woogaroo Subgroup soil and landscape example 2:

Smaller occurrences of these landscapes are found in a narrow belt from Round Mountain to Dulbolla, in the lower portions of the landscape at Allan Creek and in an isolated pocket at the base of Mount Barney. In these locations they are bordered on either side by younger Marburg Subgroup (Gatton Sandstone and Koukandowie Formation) members, possibly as a result of anticline activity.



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and slopes of undulating to rolling rises and low hills (rarely steep hills). Slope 2-30%.	Very shallow to moderately deep, strongly acidic to neutral, uniformly sandy to loamy soils with <15% clay, over sandstone from 0.2 m. Well drained.	***Yarrabilba* (Ya)** (Leptic/Bleached Leptic Tenosol, Brown/Grey Orthic Tenosol, Leptic Rudosol)
2	Slopes and crests on undulating to rolling rises and low hills. Slope up to 30%.	Moderately deep to deep, frequently bleached, brown (rarely red) texture contrast soils. Subsoils are strongly acidic to neutral, frequently mottled and may be slightly to moderately saline or sodic. Imperfectly to moderately well drained.	***Kooralbyn* (Ko)** (Brown Chromosol or Kurosol, Red Chromosol or Kurosol)
3	Slopes of low hills. Slopes 1–15%.	Moderately deep to deep strongly acidic to neutral, grey and yellow, mottled and frequently bleached, texture contrast soils. Subsoils may be saline and/or occasionally sodic. Poorly to imperfectly drained.	***Clutha* (Cl)** (Grey/Yellow Chromosol or Kurosol, Grey Kandosol or Dermosol)
4 & 5	Mid and lower slopes of rises and low hills. Slope <20%.	Deep to very deep, bleached, mottled, acidic to neutral, grey, sodic texture contrast soils formed on sandstone (rarely siltstone). May be saline. Poorly to imperfectly drained.	***Lowood* (Lw)** (Grey Sodosol, Grey Chromosol, Grey Kurosol)

Low hills and rises at the base of larger Gatton sandstone hills are the dominant landscape features in these areas, occasionally with long lower slopes or small valley flats in between. Shallow, sandy Tenosols (*Yarrabilba* soils) are found on steeper, higher crests and upper slopes while lower crests and upper slopes tend to exhibit red and brown acidic to neutral Kurosols and Chromosols (*Kooralbyn* soils). Slopes are characterised by the presence of brown yellow and grey texture contrast and gradational soils (*Kooralbyn* & *Clutha*) while lower gentler slopes tend towards the higher sodicity *Lowood* soils.

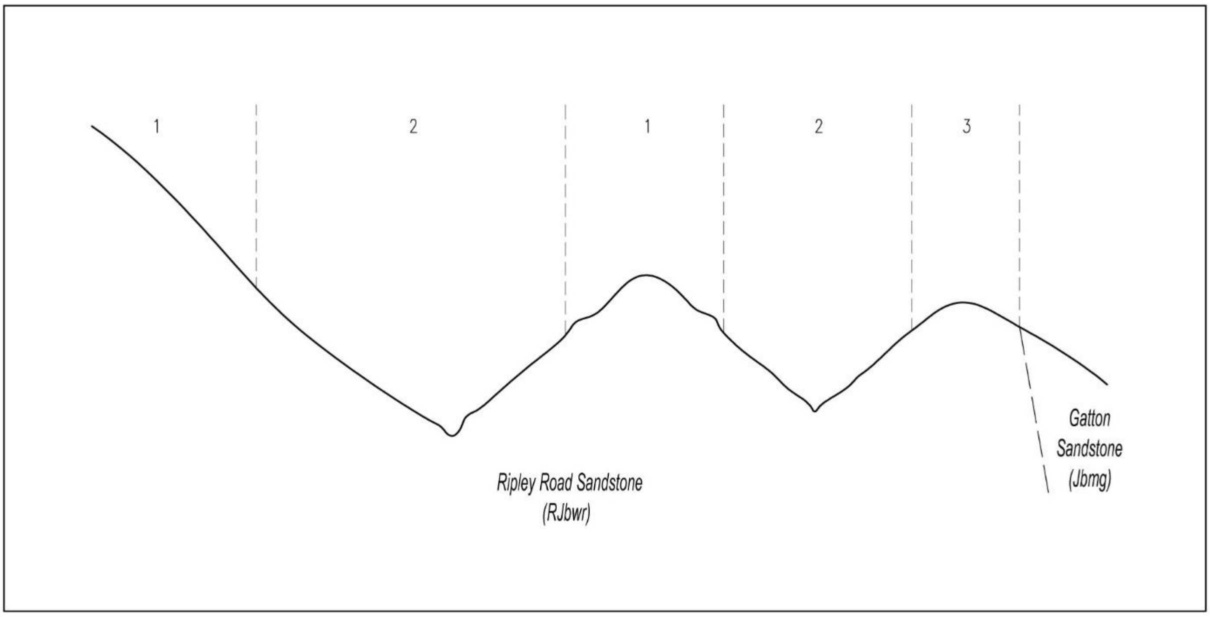
Current land use in these landscapes is grazing (where cleared) and agricultural land class is C2 to C3 with some areas of D. Agricultural land use is limited by erosion risk, soil water availability, permeability and drainage as listed in Table 9.

Table 9. Major limitations to agricultural suitability in Landscape 2 on Woogaroo Subgroup

Soil Profile Class	Significant agricultural suitability limitations
Yarrabilba (Ya)	Erosion, slope, soil depth, soil water availability, nutrient deficiency.
Kooralbyn (Ko)	Erosion, pH, soil water availability, nutrient deficiency.
Clutha (Cl)	Erosion, soil water availability, nutrient deficiency, permeability, drainage.
Lowood (Lw)	Soil water availability, erosion, subsoil erosion, nutrient deficiency, pH, permeability, drainage.

9.5.3. Woogaroo Subgroup soil and landscape example 3:

A further extension of this landscape appears at New Beith where approximately 900 hectares of Ripley Road Sandstone is located and extends westward beyond the project boundary, while being bounded by Gatton Sandstone to the east.



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and slopes of undulating to rolling rises and low hills. Slope 2-30%.	Very shallow to moderately deep, strongly acidic to neutral, uniformly sandy to loamy soils with <15% clay, over sandstone from 0.2 m. Well drained.	***Yarrabilba* (Ya)** (Leptic/Bleached Leptic Tenosol, Brown/Grey Orthic Tenosol, Leptic Rudosol)
2	Slopes of low hills. Slopes 1–15%.	Moderately deep to deep strongly acidic to neutral, grey and yellow, mottled and frequently bleached, texture contrast soils. Subsoils may be saline and/or occasionally sodic. Poorly to imperfectly drained.	***Clutha* (Cl)** (Grey/Yellow Chromosol or Kurosol, Grey Kandosol or Dermosol)
3	Slopes and crests on undulating to rolling rises and low hills. Slope up to 30%.	Moderately deep to deep, frequently bleached, brown (rarely red) texture contrast soils. Subsoils are strongly acidic to neutral, frequently mottled and may be slightly to moderately saline or sodic. Imperfectly to moderately well drained.	***Kooralbyn* (Ko)** (Brown Chromosol or Kurosol, Red Chromosol or Kurosol)

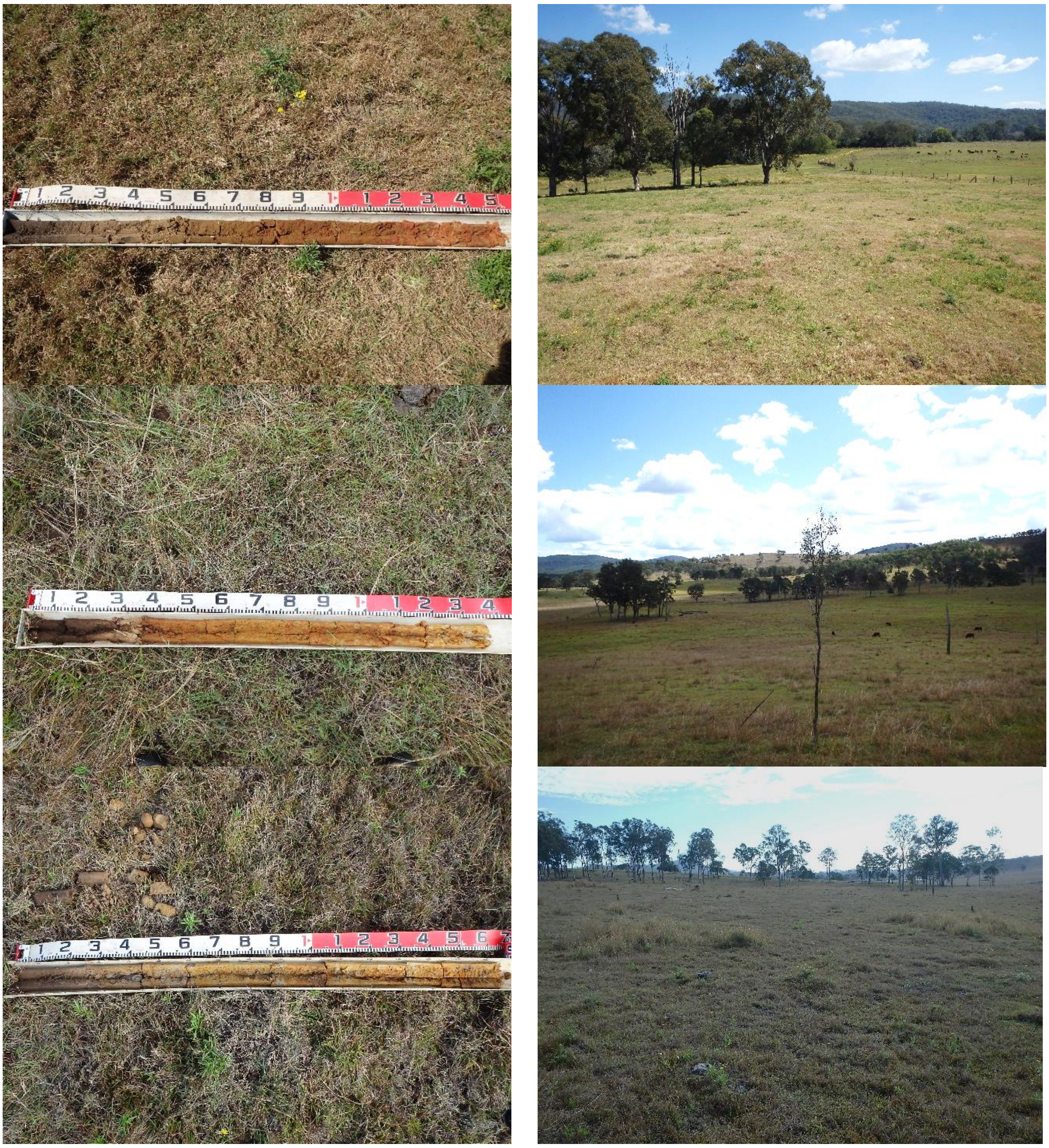


Figure 36. *Kooralbyn, Clutha* and *Lowood* soil examples. Top row: *Kooralbyn* soil core and landscape (Site 2233); Second row: *Clutha* soil core and landscape (Site 425); Third row: *Lowood* soil core and landscape (Site 549).

A continuous sequence of undulating to rolling low hills form this landscape which contains a narrow range of largely acidic soils. These range from shallow sandy Tenosols (*Yarrabilba*) on crests to variously coloured Kurosols, Chromosols and Dermosols (*Clutha* & *Kooralbyn*) on slopes and gentler crests.

Land use in this area is not currently agricultural, likely due to poor quality soils. Major sections have been given over to residential development, the area of which is steadily increasing. Agricultural land class is C1 to C2 and the major limitations to agricultural use include erosion risk, soil water availability and nutrient deficiency as listed in Table 10.

Table 10. Major limitations to agricultural suitability in Ripley Road Sandstone landscapes

Soil Profile Class	Significant agricultural suitability limitations
Yarrabilba (Ya)	Erosion, slope, soil depth, soil water availability, nutrient deficiency.
Clutha (Cl)	Erosion, soil water availability, nutrient deficiency, permeability, drainage.
Kooralbyn (Ko)	Erosion, pH, soil water availability, nutrient deficiency.

9.6. Soils and landscapes of the Marburg Subgroup (Jbmg, Jbmk, Jbmh, Jbm)

The Jurassic period Marburg Subgroup includes Gatton Sandstone, Koukandowie Formation and Heifer Creek Sandstone and covers approximately 1/3 of the study area (85 593 ha). Originally this geology group was sandwiched between the overlying Walloon Coal Measures and the underlying Woogaroo Subgroup, however, following folding and erosion events it is now exposed along the highest elevations of the western edge of the study area and wraps around to take in a significant portion of the northern and north-eastern areas. Its lithology encompasses lithofeldspathic labile and sublabile to quartzose sandstone, siltstone and smaller areas of shale, minor coal and ferruginous oolite marker.

Residential and rural residential development is common on these landscapes in areas such as Jimboomba, Flagstone, Undullah and Kooralbyn.

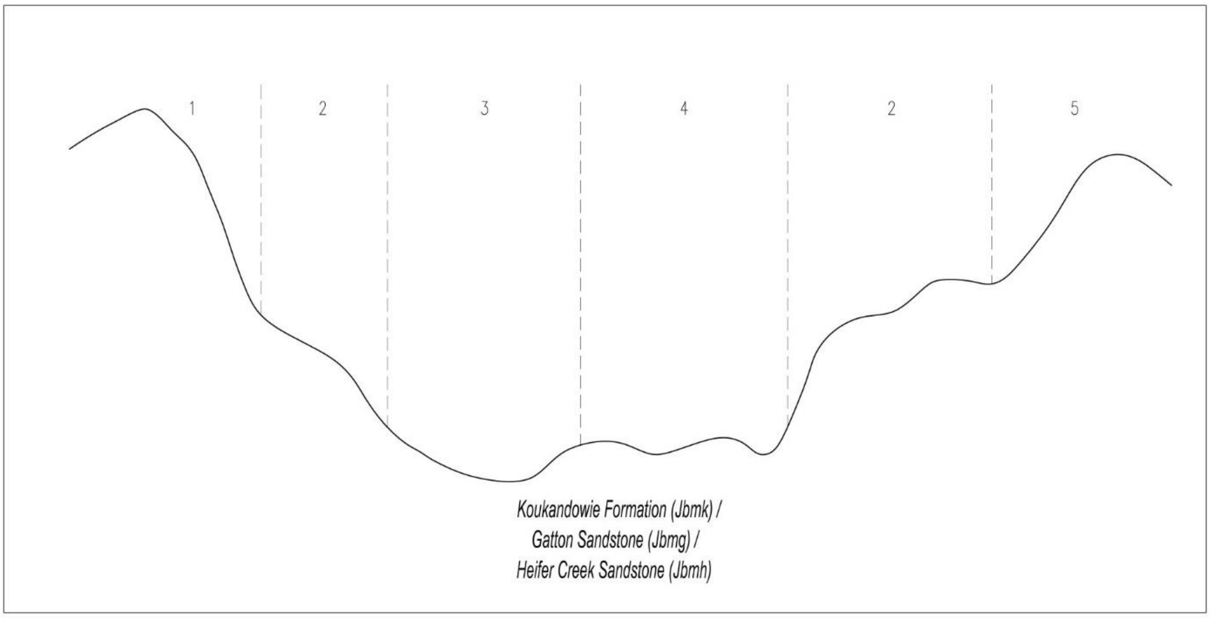
The complex combinations of lithology and landform produce a range of landscapes and soils, which are represented below in eight different example landscape sequences.

9.6.1. Marburg Subgroup soil and landscape examples 1(a) and 1(b): Knapp and Tamrookum Creeks

Landforms in Knapp and Tamrookum Creeks range from undulating rises to steep hills and support an equally wide range of soils. Shallow to moderately deep red Tenosols, Chromosols, Dermosols, Kurosols and Sodosols (*Woollaman, Rathdowney* and *Cedar Vale*) can be found on crests, ridges and upper slopes. On mid slopes brown, yellow and grey Dermosols are far more common (*Glenoake & Mundoolun*). In lower parts of the landscape on gentler slopes Sodosols and sodic Chromosols are prevalent (*Koukandowie & Lowood*) as are poorly drained Dermosols (*Richards* soils). Small areas of alluvial deposition along Knapp and Tamrookum Creeks has formed narrow bands of weakly structured Kandosols (*Logan*).

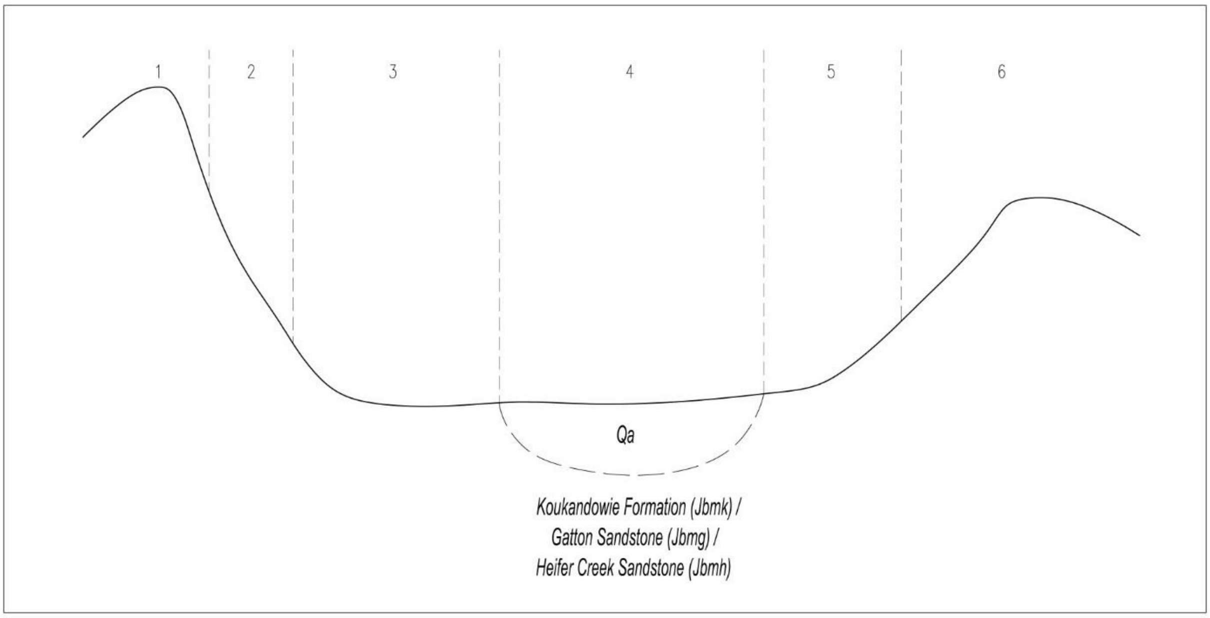
Potential agricultural use of these soils is limited to well-managed grazing, and careful grazing management is required to maintain ground cover or soil erosion will result, particularly on steeper slopes or where sodic subsoils are exposed. Agricultural land class is predominately C2 or C3 with significant areas of D and smaller areas of A2 or C1 on lower slopes and alluvium. Limitations to agricultural suitability in these landscapes are listed in Table 11.

Example 1(a): Knapp Creek



Unit	Landform	Soil Description	Soil Profile Class
1	Crests, ridges, upper slopes and steeper mid slopes of rolling to steep rises, low hills and hills. Slope up to >30%.	Moderately deep to deep, red, acidic to neutral, frequently bleached texture contrast soils (also gradational to uniformly fine soils) over sandstone or siltstone from 0.6 m. Occasionally mottled and/or sodic. Moderately well drained to well drained.	***Rathdowney* (Ra)**(Red Chromosol, Red Dermosol, Red Sodosol)
2	Crests and slopes of rolling to steep low hills and hills. Slope 1-25%.	Moderately deep, acidic to neutral, brown and yellow, occasionally mottled, gradational and uniformly fine soils. Sub soils are frequently alkaline and calcic below 0.6 m. Moderately well to well drained.	***Glenoake* (Gl)**(Brown Dermosol, Yellow Dermosol)
3	Hillslopes, crests and ridges on undulating and rolling rises and low hills. Slope <25%.	Moderately deep to very deep, sodic, bleached, brown and yellow texture contrast soils on siltstone and sandstone. Subsoils are neutral to strongly alkaline, mottled, occasionally calcic and/or saline. Imperfectly drained.	***Koukandowie* (Kk)**(Brown Sodosol, Sodic Brown or Yellow Chromosol)
	Mid and lower slopes of undulating to rolling rises and low hills. Slope <20%.	Deep to very deep, bleached, mottled, acidic to neutral, grey, sodic texture contrast soils formed on sandstone (rarely siltstone). May be saline. Poorly to imperfectly drained.	***Lowood* (Lw)**(Grey Sodosol, Grey Chromosol, Grey Kurosol)
4	Slopes of undulating rises to steep hills. Slope 4 to >30%.	Shallow, slightly acidic brown or grey texture contrast to gradational soils on sandstone. Soils are frequently bleached and/or mottled and may also be slightly saline. Moderately well drained.	***Mundoolun* (Mu)** (Brown/Grey Chromosol, Brown Kandosol, Brown Dermosol)
5	Crests and upper slopes of rolling to steep rises, low hills and hills. Slopes up to 40%.	Very shallow to shallow, red, strongly acidic to neutral texture contrast, gradational or uniformly fine soils over sandstone or siltstone from 0.3 m. Imperfectly to well drained.	***Cedar Vale* (Cv)** (Red Chromosol, Dermosol, Kurosol)

Example 1(b): Tamrookum Creek



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and slopes or benches of undulating to rolling rises and low hills. Slope 1 to >40%	Very shallow to moderately deep, acidic to neutral, uniformly sandy to loamy soils over sandstone from 0.25 m. Well drained or rapidly drained.	***Woollaman* (Wm)** (Leptic or Bleached Leptic Tenosol, Brown Orthic Tenosol, Leptic Rudosol)
2	Slopes of undulating rises to steep hills. Slope 4 to >30%.	Shallow, slightly acidic brown or grey texture contrast to gradational soils on sandstone. Soils are frequently bleached and/or mottled and may also be slightly saline. Moderately well drained.	***Mundoolun* (Mu)** (Brown/Grey Chromosol/, Kandosol/Dermosol)
	Crests and upper slopes of rolling to steep rises, to hills. Slopes up to 40%.	Very shallow to shallow, red, strongly acidic to neutral texture contrast, gradational or uniformly fine soils over sandstone or siltstone from 0.3 m. Moderately well drained to well drained.	***Cedar Vale* (Cv)** (Red Chromosol, Dermosol, Kurosol)
3	Mid and lower slopes and flats of undulating to rolling rises, low hills and hills. Slope <15%.	Moderately to very deep, mottled, grey, slightly acidic to alkaline gradational or uniformly fine soils over siltstone or sandstone from 0.65 m. Subsoils may be slightly sodic and/or mildly saline. Poorly to imperfectly drained.	***Richards* (Ri)** (Grey Dermosol)
4	Levees, plains and stream channels on alluvial and flood plains and terraces.	Deep to very deep, brown and black, neutral, uniformly medium textured soils on alluvium. Subsoils are massive or weakly structured, rarely mottled and not gravelly. Buried alluvial horizons at depth. Moderately well drained.	***Logan (SEQ)* (Lg)** (Brown Kandosol, Black Kandosol)
5	Hillslopes, crests and ridges on undulating and rolling rises and low hills. Slope <25%.	Moderately deep to very deep, sodic, bleached, brown and yellow texture contrast soils on siltstone and sandstone. Subsoils are neutral to strongly alkaline, mottled, occasionally calcic and/or saline. Moderately well drained.	***Koukandowie* (Kk)** (Brown Sodosol, Brown or Yellow Chromosol)
	Mid and lower slopes of undulating to rolling rises and low hills. Slope <20%.	Moderately deep to very deep, bleached, mottled, acidic to neutral, grey, sodic texture contrast soils formed on sandstone (rarely siltstone). May be saline. Poorly to imperfectly drained.	***Lowood* (Lw)** (Grey Sodosol, Grey Chromosol, Grey Kurosol)
6	Crests and upper slopes of rolling to steep rises, to hills. Slopes up to 40%.	Very shallow to shallow, red, strongly acidic to neutral texture contrast, gradational or uniformly fine soils over sandstone or siltstone from 0.3 m. Imperfectly to well drained.	***Cedar Vale* (Cv)** (Red Chromosol, Dermosol, Kurosol)
	Crests, ridges, upper and steeper mid slopes of rolling to steep rises to hills. Slope up to >30%.	Moderately deep, red, acidic to neutral, frequently bleached texture contrast soils (also gradational to uniformly fine soils) over sandstone or siltstone from 0.6 m. Occasionally mottled and/or sodic. Moderately well to well drained.	***Rathdowney* (Ra)** (Red Chromosol, Red Dermosol, Red Sodosol)

Table 11. Major limitations to agricultural suitability in Marburg Subgroup landscape 1

Soil Profile Class	Significant agricultural suitability limitations
Rathdowney (Ra)	Erosion, soil water availability, nutrient deficiency, slope, landscape complexity.
Woollaman (Wm)	Erosion, soil water availability, nutrient deficiency, pH, soil depth, rockiness, slope, landscape complexity.
Glenoake (Gl)	Erosion, soil water availability, nutrient deficiency, pH, slope, landscape complexity.
Koukandowie (Kk)	Erosion, subsoil erosion, soil water availability, nutrient deficiency, permeability, drainage, landscape complexity.
Lowood (Lw)	Soil water availability, erosion, subsoil erosion, nutrient deficiency, pH, permeability, drainage, landscape complexity
Richards (Ri)	Soil water availability, permeability, drainage, landscape complexity.
Logan (SEQ) (Lg)	Frost, soil water availability, nutrient deficiency, landscape complexity.
Mundoolun (Mu)	Erosion, soil water availability, nutrient deficiency, soil depth, slope, landscape complexity.
Cedar Vale (Cv)	Erosion, soil water availability, nutrient deficiency, soil depth, slope, landscape complexity.

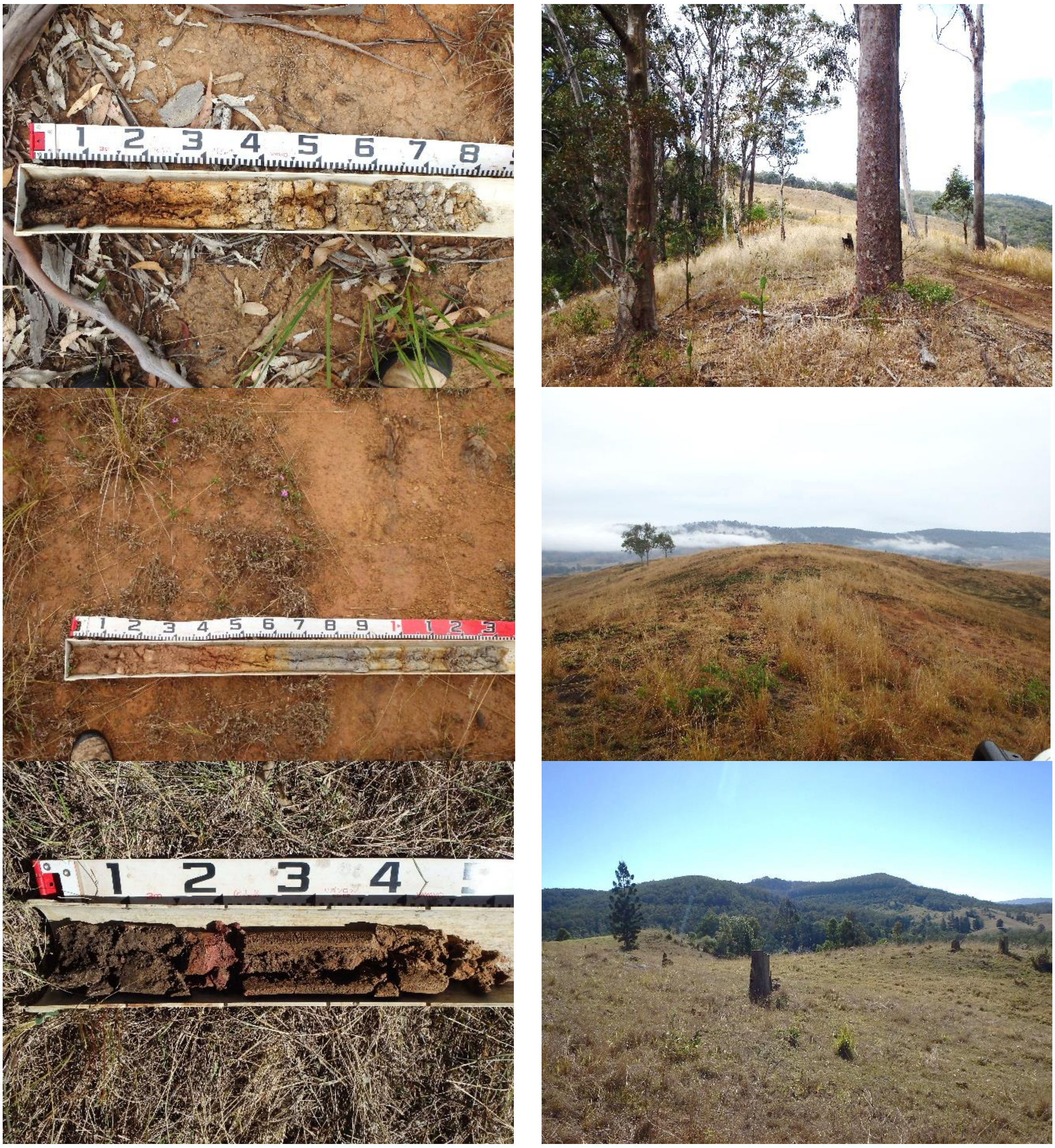
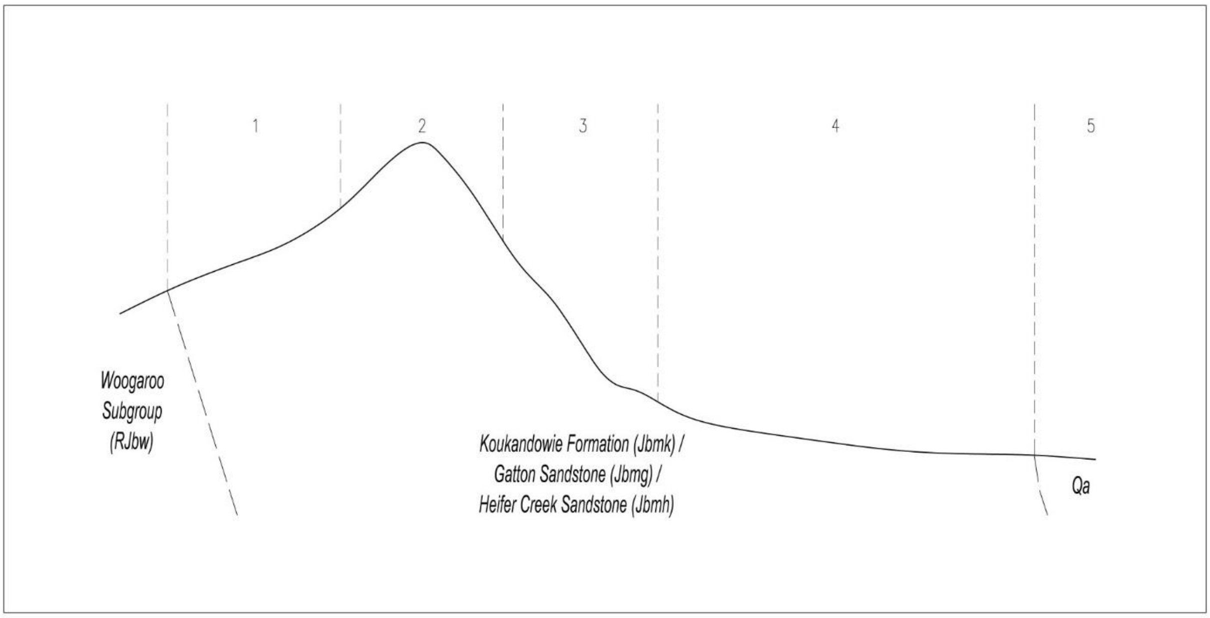


Figure 37. *Glenoake*, *Cedar Vale* and *Mundoolun* soil examples. Top row: *Glenoake* soil core and landscape (Site 401 & 402); Middle row: *Cedar Vale* soil core and landscape (Site 398); Bottom row: *Mundoolun* soil core and landscape (Site 522).

9.6.2. Marburg Subgroup soil and landscape example 2: Josephville

Josephville Marburg Group landscapes are dominated by undulating to rolling rises and low hills, with occasional hills and steeper low hills and rises. Ridges are generally aligned north to south with slope aspect due east or west.



Unit	Landform	Soil Description	Soil Profile Class
1	Slopes (rarely crests) of undulating to rolling rises and low hills. Slope 2-25%.	Moderately deep to deep mottled and/or bleached, acidic to neutral, brown and yellow texture contrast soils on sandstone. May be saline. Imperfectly to moderately well drained.	***Birnam* (Bi)** (Brown/Yellow Chromosol, Black Chromosol)
2	Crests, ridges, upper slopes and steeper mid slopes of rolling to steep rises, low hills and hills. Slope up to >30%.	Moderately deep to deep, red, acidic to neutral, frequently bleached texture contrast soils (also gradational to uniformly fine soils) over sandstone or siltstone from 0.6 m. Occasionally mottled and/or sodic. Moderately well drained to well drained.	***Rathdowney* (Ra)** (Red Chromosol, Red Dermosol, Red Sodosol)
3	Mid and lower slopes of undulating rises to rolling low hills. Slope 2-20%.	Deep to very deep, brown, neutral to alkaline texture contrast soils formed on sandstone (rarely siltstone). Bleached surfaces over frequently mottled brown, yellow and grey clays. Imperfectly to moderately well drained.	***Knapp* (Kn)** (Brown Chromosol)
	Slopes of undulating rises to rolling low hills. Slope <10%.	Deep to very deep, brown, strongly acidic, texture contrast soils formed on sandstone (rarely siltstone). Bleached surfaces over mottled brown and grey clays (rarely sodic). Imperfectly drained.	***Knapp Acidic Phase* (KnAp)** (Brown Kurosol)
4	Hillslopes, crests and ridges on undulating and rolling rises and low hills. Slope <25%.	Moderately deep to very deep, sodic, bleached, brown and yellow texture contrast soils on siltstone and sandstone. Subsoils are neutral to strongly alkaline, mottled, occasionally calcic and/or saline. Imperfectly drained.	***Koukandowie* (Kk)** (Brown Sodosol, Brown or Yellow Chromosol)
	Mid and lower slopes of undulating to rolling rises and low hills. Slope <20%.	Moderately deep to very deep, bleached, mottled, acidic to neutral, grey, sodic texture contrast soils formed on sandstone (rarely siltstone). May be saline. Poorly to imperfectly drained.	***Lowood* (Lw)** (Grey Sodosol, Grey Chromosol, Grey Kurosol)
5	Plains and terrace plains on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)

A range of red, moderately deep soils (*Rathdowney*) populate crests and upper slopes transitioning into brown and yellow Chromosol and Kurosols (*Birnam* & *Knapp*) on mid and lower slopes. The lowest landscape positions here are filled by moderately deep to very deep, and frequently sodic, texture contrast soils of *Koukandowie* and *Lowood*. The eastern facing slopes terminate when contacting the Logan River alluvium, in this case comprised of deep to very deep Black Vertosols (*Bell* (SEQ)), although other alluvial soils such as *Payne, Bremer, Beausang* or *Gunyah* may be present.

As with most soils in these landscapes, agricultural potential is limited largely to grazing (with the exception of alluviums). Agricultural land classifications are C2 to C3 with small areas of C1 possibly available for improved pasture cultivation. Major suitability limitations are soil erosion risk, soil water availability, nutrient deficiency and drainage as listed in Table 12.

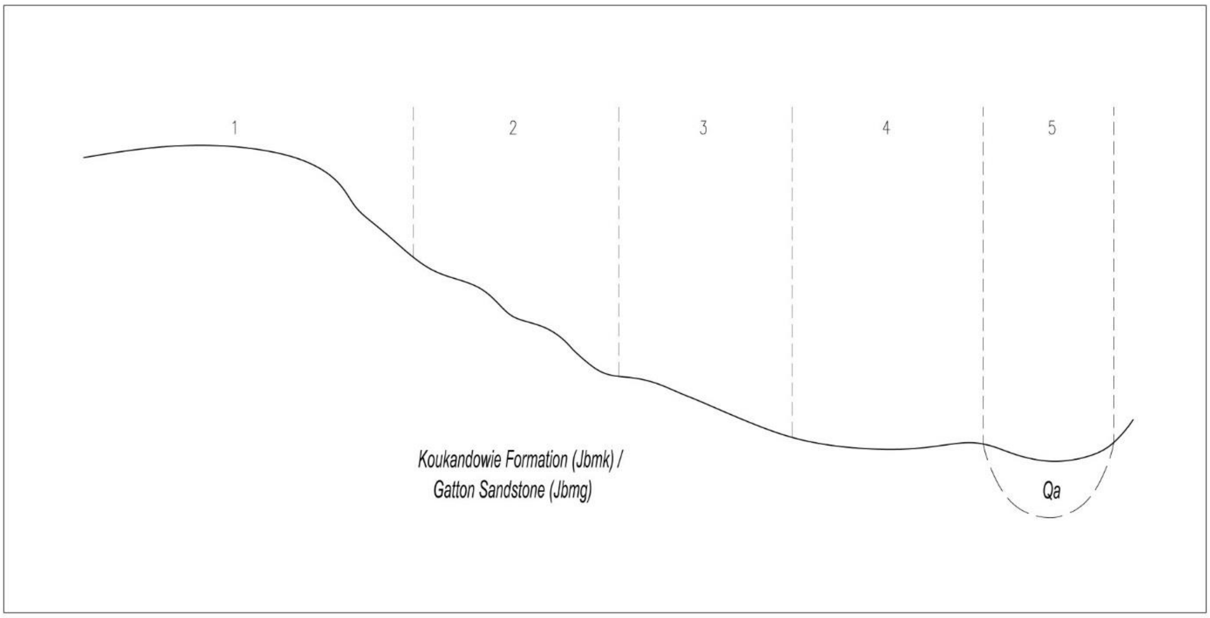
Table 12. Major limitations to agricultural suitability in Marburg Subgroup landscape 2

Soil Profile Class	Significant agricultural suitability limitations
Birnam (Bi)	Erosion, soil water availability, nutrient deficiency, permeability, landscape complexity.
Rathdowney (Ra)	Erosion, soil water availability, nutrient deficiency, slope, landscape complexity.
Koukandowie (Kk)	Erosion, subsoil erosion, soil water availability, nutrient deficiency, permeability, drainage, landscape complexity.
Lowood (Lw)	Erosion, subsoil erosion, soil water availability, nutrient deficiency, pH, permeability, drainage.

Figure 38. *Birnam* soil core and lower slope landscape (Site 599)

9.6.3. Marburg Subgroup soil and landscape example 3: Burnett Creek

Burnett creek is located in a relatively narrow valley running east towards the junction with the Logan River at Bigriggan, it continues from there on toward Rathdowney. Various small alluvial flats in the base of the valley are surrounded by rolling to steep hills of the Marburg Group.



Unit	Landform	Soil Description	Soil Profile Class
1	Crests, ridges, mid and upper slopes of rolling to undulating rises to steep hills. Slope 5-35%.	Moderately deep to deep, acidic, frequently bleached, red, uniformly fine, gradational or texture contrast soils formed on siltstone and sandstone. Subsoils are strongly acidic and frequently mottled. Moderately well to well drained.	***Flanagan* (Fl)** (Red Dermosol, Red Kurosol)
2	Crests, ridges, upper slopes and steeper mid slopes of rolling to steep rises, low hills and hills. Slope up to >30%.	Moderately deep to deep, red, acidic to neutral, frequently bleached texture contrast soils (also gradational to uniformly fine soils) over sandstone or siltstone from 0.6 m. Occasionally mottled and/or sodic. Moderately well drained to well drained.	**Rathdowney (Ra)** (Red Chromosol, Red Sodosol, Red Dermosol)
3	Slopes (rarely crests) of undulating to rolling rises and low hills. Slope 2-25%.	Moderately deep to deep mottled and/or bleached, acidic to neutral, brown and yellow texture contrast soils on sandstone. May be saline. Imperfectly to moderately well drained.	***Birnam* (Bi)** (Brown/Yellow Chromosol, Black Chromosol)
4	Mid and lower slopes and flats of rolling low hills, hills and plains. Slope 1-15%.	Deep to very deep, neutral to alkaline, frequently mottled, brown and yellow gradational and uniformly fine soils formed on siltstone, occasionally over buried horizons from 0.6 m. Imperfectly to moderately well drained.	***Dulbolla* (Db)** (Brown/Yellow Dermosol)
	Crests and slopes (rarely flats) of rolling hills. Slope 1-10%.	Deep to very deep, sodic, neutral to alkaline, frequently mottled, brown gradational and uniformly fine soils on siltstone and sandstone, occasionally over buried horizons. Subsoils become strongly alkaline and are frequently calcic and slightly saline. Imperfectly drained.	***Dulbolla Sodic Phase* (DbSp)** (Sodic Brown Dermosol)
5	Plains, terrace plains, levees and channel benches on flood plains and terraces.	Deep to very deep brown and grey texture contrast soils. Sandy loam and clay loam surfaces over sandy clay loam to medium heavy clay. Subsoils are neutral to alkaline and occasionally calcic and/or mottled, slightly saline or sodic at depth. Poorly to moderately well drained.	***Sippel* (Sl)** (Brown Chromosol, Grey Chromosol)

Moderately deep to deep, acidic red Dermosols and Kurosols (*Flanagan*) can be found on gently inclined crests and gentle to steep upper slopes, while adjacent upper (and some mid) slopes have a range of similar, but less acidic, red soils (*Rathdowney*) that may also be more sodic. On mid to lower slopes brown and yellow Chromosols and Dermosols (*Birnam* & *Dulbolla*) may be found in conjunction with sodic brown Dermosols (*Dulbolla Sodic Phase*) which are more common on foot slopes. In this example the alluvium at the current valley floor is a brown to grey Chromosol (*Sippel*), however, a number of alluvial soils may be present prior to the Logan River junction including other brown/yellow Chromosols (*Kilmoylar*) and black/brown/grey Dermosols (*Lockrose*).

Figure 39. *Dulbolla Sodic Phase* and *Sippel* soils and landscapes. Top row: *Dulbolla Sodic Phase* soil core and landscape (Site 389); Bottom row *Sippel* soil core and landscape.

This landscape is currently being used for grazing with areas of cropping/improved pasture occurring on alluvial flats. The dominant agricultural land classification is C2 or C3 (grazing) with the alluvial flats being class B. The main limitations to agricultural land suitability (other than on the alluvium) are listed in Table 13.

Table 13. Major limitations to agricultural suitability in Marburg Subgroup landscape 3

Soil Profile Class	Significant agricultural suitability limitations
Flanagan (Fl)	Erosion, nutrient deficiency, pH, rockiness, landscape complexity.
Rathdowney (Ra)	Erosion, soil water availability, nutrient deficiency, slope.
Birnam (Bi)	Erosion, soil water availability, nutrient deficiency, permeability, landscape complexity.
Dulbolla (Db)	Erosion, slope.
Dulbolla Sodic Phase (DbSp)	Subsoil erosion, soil water availability, permeability, drainage.
Sippel (Sl)	Frost, soil water availability, nutrient deficiency, landscape complexity.

9.6.4 Marburg Subgroup soil and landscape example 4(a): Cedar Grove

These landscapes are at lower elevations than the other Marburg Subgroup landscapes and are made up of undulating to rolling rises and low hills close to the Logan River at Cedar Grove. Soils on crests are shallow Tenosols (rarely Rudosols) over sandstone (*Woollaman*) grading to moderately deep, grey Chromosols and Kurosols (*Pine Vale*) on upper and mid slopes. Lower slopes and gentle mid slopes exhibit moderately deep to deep Grey Chromosols and Grey Kurosols which may also be saline (*Pine Vale* & *Stockleigh*).

Unit	Landform	Soil Description	Soil Profile Class
1	Mid slopes of undulating to rolling rises and low hills. Slope <20%.	Moderately deep to deep, grey, strongly acidic to neutral, bleached, mottled texture contrast soils on sandstone or siltstone. May be saline. Imperfectly drained.	***Pine Vale* (Pv)** (Grey Chromosol, Grey Kurosol)
2	Crests and upper slopes (rarely mid slopes or benches) of undulating to rolling rises and low hills. Slope 1 to >40%.	Very shallow to moderately deep, acidic to neutral, uniformly sandy to loamy soils over sandstone from 0.25 m. Well drained or rapidly drained.	***Woollaman* (Wm)** (Leptic/Bleached Leptic Tenosol, Brown Orthic Tenosol, Leptic Rudosol)
3	Lower slopes of undulating to rolling rises and low hills. Slope <20%.	Moderately deep to deep, grey, strongly acidic to neutral, bleached, mottled texture contrast soils on sandstone or siltstone. May be saline. Imperfectly drained.	***Pine Vale* (Pv)** (Grey Chromosol, Grey Kurosol)
4	Slopes of undulating to rolling rises and low hills. Slopes <15%.	Moderately deep to very deep, acidic to neutral, grey, texture-contrast soil on sandstone. Subsoils are mottled and may become alkaline or saline at depth. Imperfectly drained.	***Stockleigh* (St)** (Grey Chromosol, Grey Kurosol)

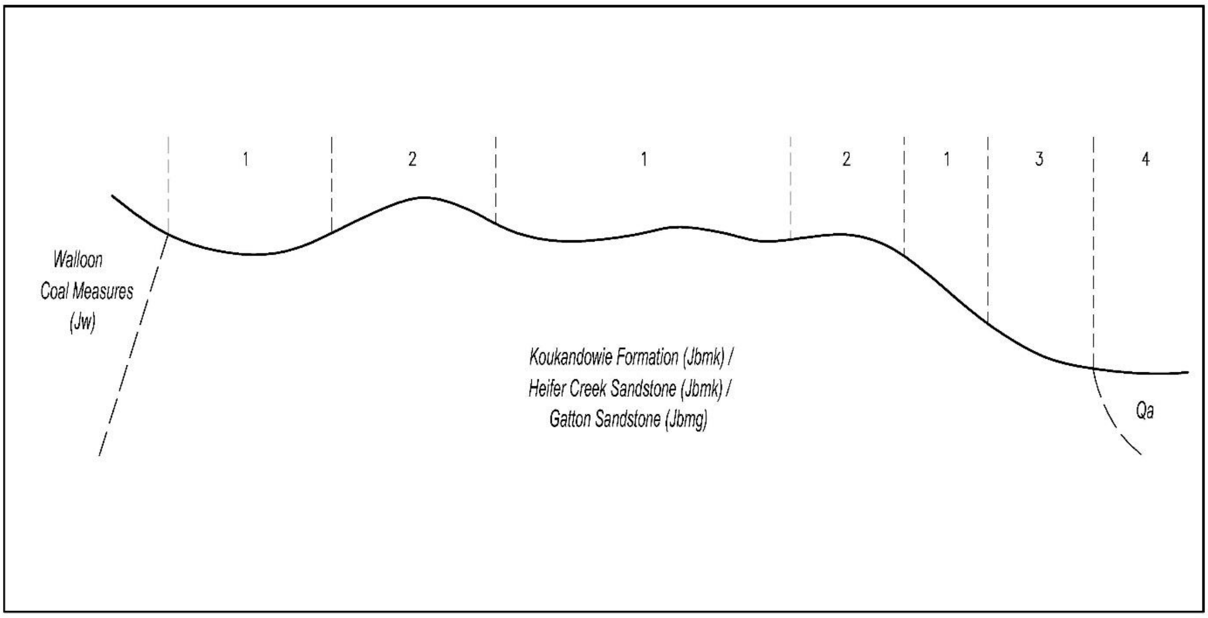
Current land uses in these landscapes include limited cultivation, grazing, forestry and major residential developments at Cedar Grove and Flagstone. Agricultural land class ranges from C1 to C3, with erosion, soil water availability and nutrient deficiency being the major limitations to agricultural use as listed in Table 14.

Table 14. Major limitations to agricultural suitability in Marburg Subgroup landscape 4(a)

Soil Profile Class	Significant agricultural suitability limitations
Pine Vale (Pv)	Erosion, soil water availability, nutrient deficiency, pH, landscape complexity, drainage.
Woollaman (Wm)	Erosion, soil water availability, nutrient deficiency, pH, soil depth, rockiness, slope, landscape complexity.
Stockleigh (St)	Erosion, soil water availability, nutrient deficiency, drainage, landscape complexity.

9.6.4. Marburg Subgroup soil and landscape example 4(b): Cedar Grove

The slopes and broad crests of these low relief landscapes offer some of the better soils formed on the Marburg Subgroup members in the form of moderately deep to very deep black and brown (occasionally grey) Vertosols (*Kagaru* & *Gould*). Other mid and lower slopes adjacent to alluvium have poorly drained and sodic Chromosols, Kurosols and Sodosols (*Lowood*) and sodic, mottled grey Dermosols (*Richards*). Various alluvial soils are possible adjacent to these rises, however, deep to giant, black, brown and grey Dermosols (*Bremer* & *Bremer Buried Phase*) are the most common.



Unit	Landform	Soil Description	Soil Profile Class
1	Lower slopes and flats of undulating to rolling rises and low hills. Slope 0-15%.	Deep to very deep, brown and black, cracking clay soils on siltstone. Subsoils are alkaline, calcic, commonly mottled, and may also be moderately saline. Imperfectly drained to well drained.	***Kagaru*** **(Ka)** (Black/Brown Vertosol)
2	Slopes (rarely broad crests) of undulating and rolling rises and low hills. Slope 2-15%.	Moderately deep to very deep, strongly acidic to neutral, brown, black and grey cracking clay soils on siltstone. Occasionally sodic. Poorly to moderately well drained.	***Gould*** **(Gd)** (Brown Vertosol, Black Vertosol, Grey Vertosol)
3	Mid and lower slopes and flats of undulating to rolling rises, low hills and hills. Slope <15%.	Moderately to very deep, mottled, grey, slightly acidic to alkaline gradational or uniformly fine soils over siltstone or sandstone from 0.65 m. Subsoils may be slightly sodic and/or mildly saline. Poorly to imperfectly drained.	***Richards*** **(Ri)** (Grey Dermosol)

Unit	Landform	Soil Description	Soil Profile Class
3	Mid and lower slopes of undulating to rolling rises and low hills. Slope <20%.	Moderately deep to very deep, bleached, mottled, acidic to neutral, grey, sodic texture contrast soils formed on sandstone (rarely siltstone). May be saline. Poorly to imperfectly drained.	***Lowood* (Lw)** (Grey Sodosol, Grey Chromosol, Grey Kurosol)
4	Plains, terrace plains, levees and fans on alluvial plains, plains, flood plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, occasionally mottled, slightly saline and/or vertic. Buried horizons are not encountered within 1.8 m. Imperfectly to moderately well drained.	***Bremer* (B)** (Black/Brown/Grey Dermosol)
	Plains, terrace plains, levees and valley flats on flood plains, alluvial plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, slightly to mildly saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well drained or imperfectly drained.	***Bremer Buried Phase* (BBP)** (Black Dermosol, Brown Dermosol, Grey Dermosol)

Due to the properties of the *Kagaru* and *Gould* soils, the agricultural potential of these landscapes is greater than those surrounding them. This is reflected in the assigned agricultural land classes which range from C1 to A2 to A1. Major limitations to agricultural land suitability are listed in Table 15.

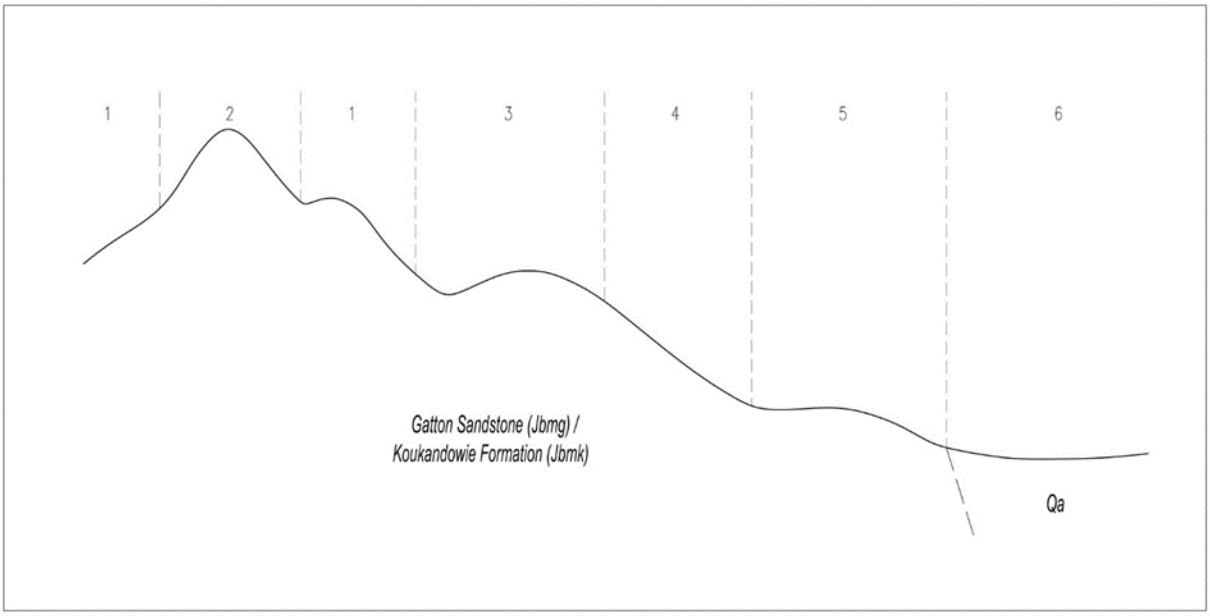
Table 15. Major limitations to agricultural suitability in Marburg Subgroup landscape 4(b)

Soil Profile Class	Significant agricultural suitability limitations
Kagaru (Ka)	Frost.
Gould (Gd)	pH.
Richards (Ri)	Soil water availability, permeability, drainage, landscape complexity.
Lowood (Lw)	Soil water availability, subsoil erosion, nutrient deficiency, pH, permeability, drainage, landscape complexity.

9.6.5. Marburg Subgroup soil and landscape example 5: Tabragalba/ Biddaddaba

Located on rises, low hills and hills of a range between the Albert River and Biddaddaba Creek (upstream of Canungra Creek) north of Mount Tabragalba, these exposed Marburg Subgroup landscapes are found at the northern edge of the younger eroded/receding Miocene basalt flows.

The highest crests and upper slopes are dominated by moderately deep red texture contrast and gradational soils (*Flanagan* & *Rathdowney*) grading to much shallower red Kurosols, Chromosols and Dermosols (*Cedar Vale*) on steeper adjacent slopes and subordinate crests. On lower landscape crests and ridges moderately deep to deep brown and yellow Sodosols, Chromosols and Kurosols occur (*Koukandowie*) before grading to sodic, grey texture contrast soils (*Lowood*) on mid and lower slopes, generally <20%. On either side of the range basalt dominated alluviums are present (*Blenheim* and *Bell (SEQ)*).



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and upper slopes of rolling to steep rises, low hills and hills. Slopes up to 40%.	Very shallow to shallow, red, strongly acidic to neutral texture contrast, gradational or uniformly fine soils over sandstone or siltstone from 0.3 m. Imperfectly drained to well drained.	***Cedar Vale*** **(Cv)** (Red Chromosol, Dermosol, Kurosol)
2	Crests, ridges and slopes of undulating to rolling rises to steep hills. Slope 5-35%.	Moderately deep to deep, acidic, frequently bleached, red, uniform, gradational or texture contrast soils formed on siltstone and sandstone. Subsoils are strongly acidic and frequently mottled. Moderately well drained to well drained.	***Flanagan*** **(Fl)** (Red Dermosol, Red Kurosol, Red Kandosol)
	Crests, ridges, upper slopes and steeper mid slopes of rolling to steep rises, low hills and hills. Slope up to >30%.	Moderately deep to deep, red, acidic to neutral, frequently bleached texture contrast soils (also gradational to uniformly fine soils) over sandstone or siltstone from 0.6 m. Occasionally mottled and/or sodic. Moderately well to well drained.	***Rathdowney*** **(Ra)** (Red Chromosol, Red Dermosol, Red Sodosol)
3	Hillslopes, crests and ridges on undulating and rolling rises and low hills. Slope <25%.	Moderately deep to very deep, sodic, bleached, brown and yellow texture contrast soils on siltstone and sandstone. Subsoils are neutral to strongly alkaline, mottled, occasionally calcic and/or saline. Imperfectly drained.	***Koukandowie*** **(Kk)** (Brown Sodosol, Brown or Yellow Chromosol)
4 & 5	Mid and lower slopes of undulating to rolling rises and low hills. Slope <20%.	Moderately deep to very deep, bleached, mottled, acidic to neutral, grey, sodic texture contrast soils formed on sandstone (rarely siltstone). May be saline. Poorly to imperfectly drained.	***Lowood*** **(Lw)** (Grey Sodosol, Grey Chromosol, Grey Kurosol)
6	Plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim*** **(Bm)** (Black Vertosol)
	Plains and terrace plains on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)*** **(Bl)** (Black Vertosol)

Grazing is currently the major land use on these landscapes with minor areas of improved pasture and turf cultivation located on alluviums. Land use is unlikely to change due to limitations such as slope, soil depth, sodicity and drainage (Table 16). Agricultural land class for this area ranges from C1 to C3, however, some pockets of ALC class B land may be present where land use limitations are not as severe.

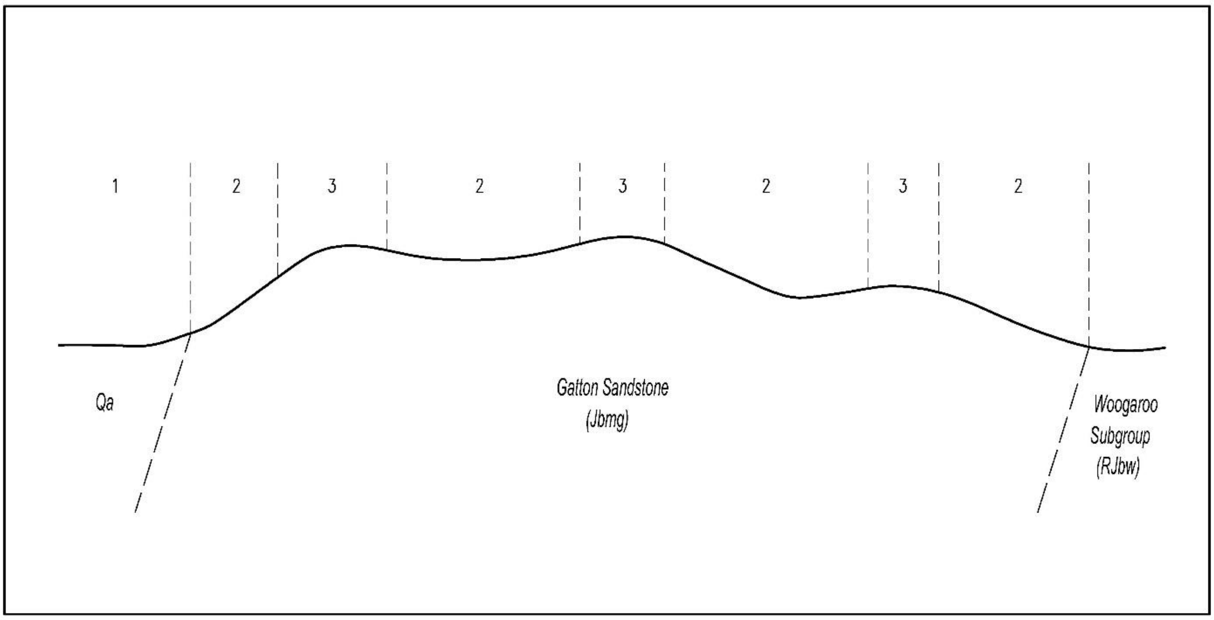
Table 16. Major limitations to agricultural suitability in Marburg Subgroup landscape 5

Soil Profile Class	Significant agricultural suitability limitations
Cedar Vale (Cv)	Erosion, soil water availability, nutrient deficiency, soil depth, slope, landscape complexity.
Flanagan (Fl)	Erosion, soil water availability, nutrient deficiency, pH, surface condition (hard setting), slope (varies), landscape complexity.
Rathdowney (Ra)	Erosion, soil water availability, nutrient deficiency, slope, landscape complexity.
Koukandowie (Kk)	Erosion, subsoil erosion, soil water availability, nutrient deficiency, permeability, drainage, landscape complexity.
Lowood (Lw)	Soil water availability, erosion, subsoil erosion, nutrient deficiency, pH, permeability, drainage, landscape complexity.

Figure 40. *Rathdowney* and *Lowood* soil examples. Top row: Sodic *Rathdowney* soil core and broad crest landscape (Site 751); Bottom row: *Lowood* soil core and lower slope landscape (Site 2238).

9.6.6. Marburg Subgroup soil and landscape example 6: Rockford Creek

This low relief Marburg Subgroup landscape of undulating rises is punctuated by shallow to moderately deep Tenosols (*Woollaman*) on hill crests with deep brown Chromosols (*Hardgrave*) on mid and lower slopes – the major unit of this landscape. These slopes grade towards poorly drained alluvial plains, swamps and terraces containing grey Vertosols and Hydrosols (*Basel* and *Waterford*).



Unit	Landform	Soil Description	Soil Profile Class
1	Drainage impaired plains, swamps, and drainage depressions.	Deep to very deep grey cracking clays on alluvium. Subsoils are neutral to alkaline and may be sodic, calcic and/or saline at depth. Poorly to imperfectly drained.	***Basel* (Bs)** (Grey Vertosol, Aquic (Grey) Vertosol, Redoxic Hydrosol)
	Plains and terrace plains on terraces and flood plains.	Deep to very deep, strongly acidic grey, brown and black cracking clays on alluvium. Subsoils are grey, mottled, strongly acidic, and/or occasionally sodic or slightly saline. Buried horizons rarely encountered within 1.8 m. Poorly to imperfectly drained.	***Waterford* (Wa)** (Grey Vertosol, Brown Vertosol, Black Vertosol)
2	Mid and lower slopes of undulating rises to rolling low hills. Slope up to 20%.	Deep to very deep, brown, neutral to alkaline, frequently mottled, texture contrast soils on sandstone (rarely siltstone or coal). Black loamy surface overlying brown medium clays, over brown and grey medium to heavy clays. Subsoils are frequently strongly alkaline and calcic. Imperfectly to moderately well drained.	***Hardgrave* (Ha)** (Brown Chromosol)
3	Crests and upper slopes of undulating to rolling rises and low hills. Slope 1 to >40%.	Very shallow to moderately deep, acidic to neutral, uniformly sandy to loamy soils over sandstone from 0.25 m. Well drained to rapidly drained.	***Woollaman* (Wm)** (Leptic/Bleached Leptic Tenosol, Brown Orthic Tenosol, Leptic Rudosol)

Agricultural use of these landscapes is limited to grazing and some cultivation on the Logan River north of Rockford Creek (on *Hardgrave*). However, large areas have also been dedicated to residential and rural residential development west, south and east of Rockford Creek towards Stockleigh. Agricultural land classes in these landscapes are C1, B, A2 and D. The major limitations to agricultural suitability are listed in Table 17.

Table 17. Major limitations to agricultural suitability in Marburg Subgroup landscape 6

Soil Profile Class	Significant agricultural suitability limitations
Basel (Bs)	Permeability and drainage.
Hardgrave (Ha)	Erosion, soil water availability.
Woollaman (Wm)	Erosion, soil water availability, nutrient deficiency, pH, soil depth, rockiness.
Waterford (Wa)	Soil water availability, pH, wetness, frost.

9.7. Soils and landscapes of the Walloon Coal Measures (Jw)

Walloon Coal Measures occupy 20 886 hectares of the study area and are found in the upper Logan River area (north of Mount Lindesay to Barney Creek); in narrow but wide spread bands from Christmas Creek to Woollaman Creek in the Logan River Catchment and Kerry to Cedar Grove in the Albert River catchment; west of Knapps Peak; and in a small area (exposed by erosion) surrounded by basalts at Darlington in the upper reaches of the Albert River. These Walloon Coal Measures are limited to low hills and rises.

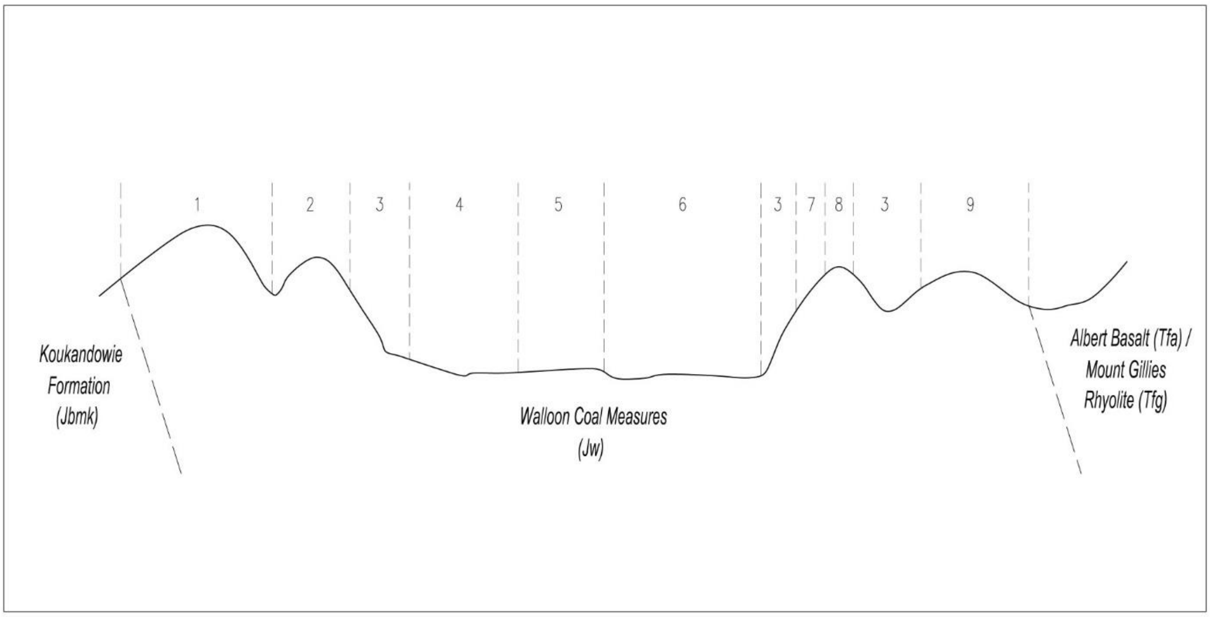
Lithology is varied including thin-bedded, claystone, shale, siltstone, lithic and sub-lithic to feldspathic arenites, and occasional coal seams, all of which are prone to changing rapidly across the landscape due to historic folding and erosion. As with the Marburg Subgroup, the lithology of the Walloon Coal Measures gives rise to a variety of soils and landscapes, however, siltstones and fine grained sandstones are more of a dominant feature. These variations are represented below in five landscape sequence examples.

With the exceptions of Beaudesert and Cedar Grove settlements, the soils of the Walloon Coal Measures remain largely in agricultural use where suitable.

9.7.1. Walloon Coal Measures soil and landscape example 1: Upper Logan River

This relatively narrow valley is flanked by undulating to rolling rises and low hills graduating to rolling hills further away from the Logan River. The Walloon Coal Measures overlie Koukandowie Formation to the west and Albert Basalt and Mount Gillies Rhyolite to the east.

Western hills contain a range of red and brown Chromosols, Kurosols and Dermosols (*Drynan* & *Nindooinbah Deep Phase*) on crests, upper slopes and elevated mid slopes. These grade down to low hills and rises with Grey Dermosols (*Lillydale*) on mid to lower slopes and Grey to Brown Sodosols (*Saville*) where slopes fall below 10%. Various alluvial soils including Grey, Yellow, Brown and Black Chromosols (*Sippel, Kilmoylar* and *Grigor*) and Dermosols (*Bremer Buried Phase*) may be present dependent upon location. Low hills and hills on the eastern side of this landscape host a mixture of Grey Chromosols, Kurosols and Dermosols (*Lillydale, Lillydale Acidic Phase* & *Brennan*) with occasional Tenosols (*Woollaman*) on narrower crests and steep upper slopes.



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and slopes of undulating to rolling rises or low hills. Slope 0-15%.	Shallow to moderately deep, red, texture contrast soil on siltstone and sandstone, generally underlain by grey clays. Subsoils are acidic or strongly acidic but may be alkaline and calcic at depth in siltstone saprolite. Subsoils are commonly mottled, rarely sodic and may be slightly or moderately saline. Poorly to imperfectly drained.	***Drynan*** **(Dn)** (Red Chromosol or Kurosol)
2	Slopes (rarely crests) of undulating to rolling rises to hills. Slopes <25%.	Deep to very deep, red or brown, neutral to strongly alkaline non-cracking uniformly fine (rarely gradational) soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over Walloon sandstone or siltstone from 1.0 m. Imperfectly to moderately well drained.	***Nindooinbah Deep Phase*** **(NiDp)** (Red or Brown Dermosol)
3	Slopes (occasionally crests) of undulating to rolling rises to hills. Slope 1-20%.	Moderately deep to very deep, grey, non-cracking, uniformly fine (rarely gradational) clay soils over sandstone and siltstone from 0.9 m. Subsoils are frequently mottled and neutral to strongly alkaline. Subsoils may also be occasionally calcic, slightly to mildly saline or rarely sodic. Poorly to imperfectly drained.	***Lillydale*** **(Ld)** (Grey Dermosol)
4	Mid and lower slopes (also flats) of undulating to rolling rises and low hills, rarely on terraces. Slope generally <10%.	Deep to very deep (rarely moderately deep) brown and grey, sodic, mottled and bleached texture contrast soils on sandstone and siltstone. Subsoils range from strongly acidic to strongly alkaline and are occasionally calcic or slightly to mildly saline at depth. Poorly drained to moderately well drained.	***Saville*** **(Sv)** (Grey or Brown Sodosol)
5	Plains, terrace plains, levees and channel benches on flood plains and terraces.	Deep to very deep brown and grey, strong texture contrast soils formed on alluvium. Sandy loam and clay loam surfaces over sandy clay loam to medium heavy clay. Subsoils are neutral to alkaline and occasionally calcic and/or mottled, slightly saline or sodic at depth. Poorly drained to moderately well drained.	***Sippel*** **(Sl)** (Brown or Grey Chromosol)
6	Plains and terrace plains on level to undulating alluvial and flood plains and terraces.	Deep to very deep, brown, neutral, texture contrast soils formed on alluvium. Commonly bleached loamy surfaces over neutral, frequently mottled brown and grey clays. Imperfectly to moderately well drained.	***Kilmoylar*** **(Km)** (Brown or Yellow Chromosol)
	Plains and levees on alluvial plains and terraces.	Moderately deep to very deep, neutral, black texture-contrast soils on Quaternary alluvium. Subsoils overlie buried alluvial horizons at depth. Imperfectly to moderately well drained.	***Grigor*** **(Gr)** (Black Chromosol)
	Plains, terrace plains, levees and valley flats on flood plains, alluvial plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils formed on alluvium. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, slightly to mildly saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well drained or imperfectly drained.	***Bremer Buried Phase*** **(BBP)** (Black, Brown or Grey Dermosol)

Unit	Landform	Soil Description	Soil Profile Class
7	Mid and upper slopes (also lower slopes and crests) of undulating to steep rises and low hills. Slope 1-20%, but may be up to 35%.6.	Moderately deep to very deep, grey, frequently bleached, mottled, strongly acidic to neutral, texture contrast soils overlying grey, brown or yellow subsoils on sandstone or siltstone. Subsoils may be sodic and/or mildly to moderately saline. Imperfectly drained.	***Brennan* (Be)** (Grey Chromosol or Kurosol)
8	Crests and upper slopes (rarely mid slopes or benches) of undulating to rolling rises and low hills. Slope 1 to >40%.	Very shallow to moderately deep, acidic to neutral, uniformly sandy to loamy soils over sandstone from 0.25 m. Well drained or rapidly drained.	***Woollaman* (Wm)** (Leptic/Bleached Leptic Tenosol, Brown Orthic Tenosol, Leptic Rudosol)
9	Slopes (very rarely crests) of undulating to rolling rises to hills. Slope 1-15%.	Moderately deep to very deep, grey, non-cracking, bleached, strongly acidic, uniformly fine and gradational soils over sandstone and siltstone from 0.6 m. Subsoils are frequently mottled. Subsoils may also be saline. Poorly to imperfectly drained.	***Lillydale Acidic Phase* (LdAp)** (Grey Dermosol)

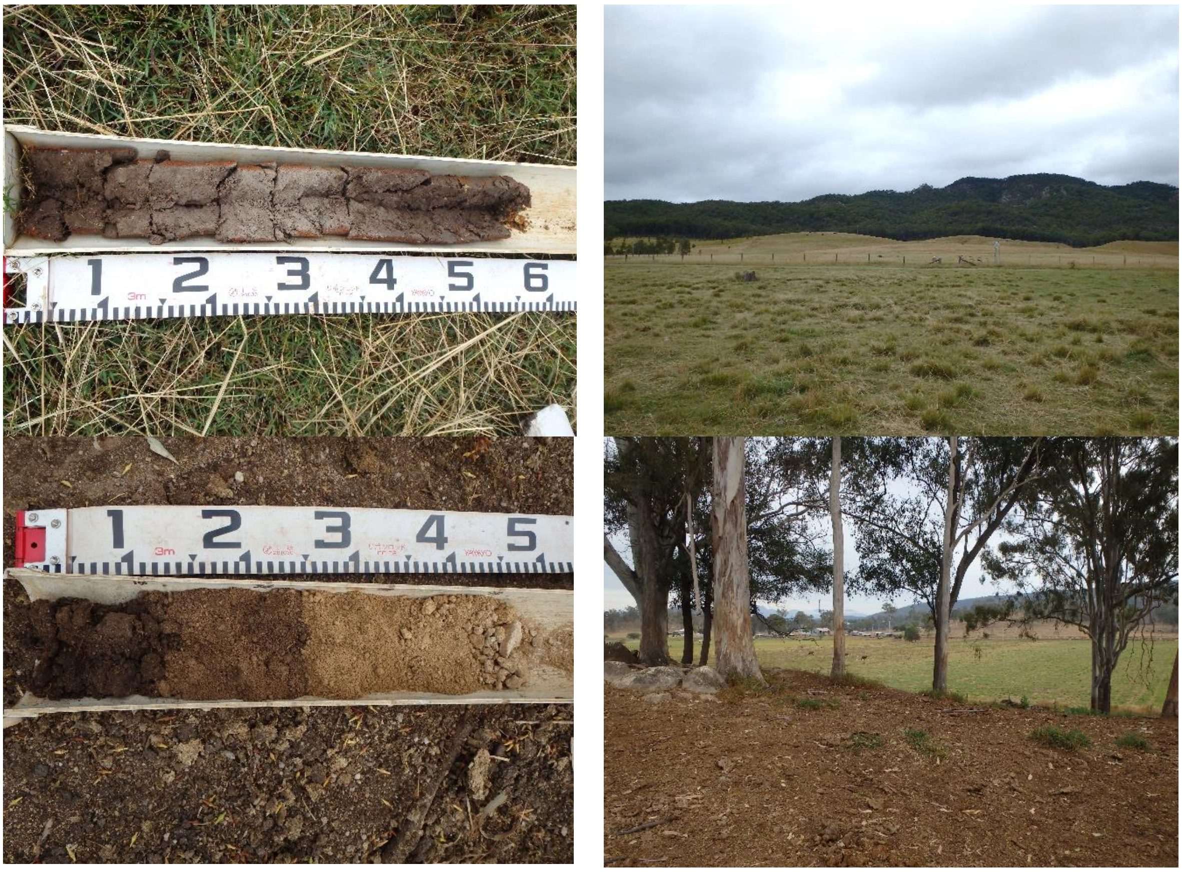


Figure 41. *Brennan* and *Woollaman* soil examples. Top row: *Brennan* soil core and landscape looking east (Site 261); Bottom row: *Woollaman* soil core and landscape on stony ridge (Site 502).

Land use in this area is mostly grazing with a history of past cropping that has reduced significantly due to less reliable rainfall. Agricultural land classes here range from C2 and C3 on rolling hills, C1 and B on rises and lower slopes of rises, and B and A2 on alluvial soils. Limitations to agricultural suitability are listed in Table 18.

Table 18. Major limitations to agricultural suitability in Walloon Coal Measures landscape 1

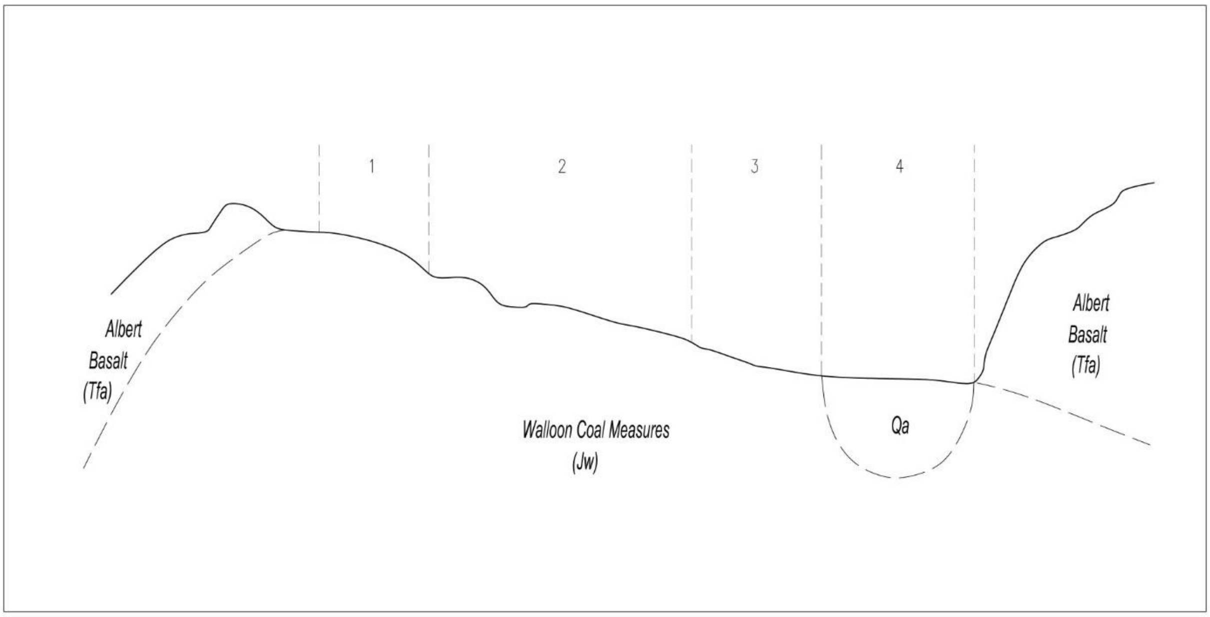
Soil Profile Class	Significant agricultural suitability limitations
Drynan (Dn)	Erosion, soil water availability, rockiness, landscape complexity.
Nindooinbah Deep Phase (NiDp)	Erosion, soil water availability, slope.
Lillydale (Ld)	Erosion, nutrient deficiency, drainage.
Lillydale Acidic Phase (LdAp)	Erosion, nutrient deficiency, drainage, pH.
Saville (Sv)	Soil water availability, nutrient deficiency, permeability, drainage.
Sippel (Sl)	Frost, soil water availability, nutrient deficiency, surface condition, permeability, drainage.
Kilmoylar (Km)	Frost, flooding, soil water availability, wetness.
Grigor (Gr)	Frost, flooding, soil water availability, wetness.
Bremer Buried Phase (BBp)	Frost, flooding, soil water availability, wetness.
Brennan (Be)	Erosion, soil water availability, nutrient deficiency, slope, landscape complexity, wetness.
Woollaman (Wm)	Erosion, soil water availability, nutrient deficiency, pH, soil depth, rockiness, slope.

9.7.2. Walloon Coal Measures soil and landscape example 2: Upper Albert River

In this small part of the study area the underlying Walloon Coal Measures appear to have been re-exposed following erosion of the younger, and overlying, Miocene basalts. This has resulted in a landscape of low hills and rises on siltstone and sandstone surrounded by higher elevation rolling low hills and hills on basalt. Alluviums here are largely basalt derived with some Walloon influence.

On upper slopes Red and Brown Dermosols (*Josephville*) are found over siltstone, which are functionally similar to those found on surrounding basalt low hills and hills. Slightly steeper mid slope positions are filled by deeper, and sometimes more acidic red, brown and, occasionally, grey Dermosols (*Nindooinbah Deep Phase, Nindooinbah Acidic Phase* & *Lillydale*) before often grading to deep to very deep, calcic black and brown Vertosols (*Kagaru*) on lower and foot slopes. Alluvial soils are mostly black Vertosols (*Bell (SEQ))* & *Cooeeimbardi*) however some Black Dermosols (*Bremer* soils) may be present.

Agricultural land classes in this area are C2 or C3 on the majority of slopes with foot slopes and alluviums being A2. Table 19 shows the limitations to agricultural suitability.



Unit	Landform	Soil Description	Soil Profile Class
1	Upper slopes of undulating to rolling rises and low hills. Slope 1-15%.	Shallow to moderately deep, red and brown, non-cracking, uniformly fine clay soils. Dark surfaces over occasionally mottled red and brown clays on sandstone and siltstone from 0.4 m Subsoils are neutral to alkaline and may be saline. Moderately well drained to well drained.	***Josephville* (Jo)** (Red or Brown Dermosol)
2	Slopes of undulating to rolling rises and low hills. Slopes <25%.	Deep to very deep, red or brown, neutral to strongly alkaline non-cracking uniformly fine (rarely gradational) soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over Walloon sandstone or siltstone from 1.0 m. Imperfectly to moderately well drained.	**Nindooinbah Deep Phase (NiDp)** (Red or Brown Dermosol)
		Moderately deep to very deep, red or brown, acidic gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Moderately well drained.	***Nindooinbah Acidic Phase* (NiAp)** (Red or Brown Dermosol)
		Moderately deep to very deep, grey, non-cracking, neutral to alkaline uniformly fine (rarely gradational) clay soils over sandstone and siltstone from 0.9 m. Subsoils are frequently mottled and neutral to strongly alkaline. Subsoils may also be occasionally calcic, slightly to mildly saline or rarely sodic. Poorly to imperfectly drained.	***Lillydale* (Ld)** (Grey Dermosol)
3	Lower slopes and flats of undulating to rolling rises and low hills. Slope 0-15%.	Deep to very deep, brown and black, cracking clay soils on siltstone. Subsoils are alkaline, calcic, commonly mottled, and may be moderately saline. Imperfectly drained to well drained.	***Kagaru* (Ka)** (Black/Brown Vertosol)
4	Plains, back plains, fans and terrace plains on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
		Deep to very deep self-mulching, neutral to alkaline, black cracking clay soils on alluvium. Subsoils are not calcic, rarely mottled and may be slightly saline. Moderately well drained, occasionally imperfectly drained.	***Cooeeimbardi* (Cb)** (Black Vertosol)
		Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, occasionally mottled, slightly saline and/or vertic. Buried horizons are not encountered within 1.8 m. Imperfectly to moderately well drained.	***Bremer* (B)** (Black, Brown or Grey Dermosol)

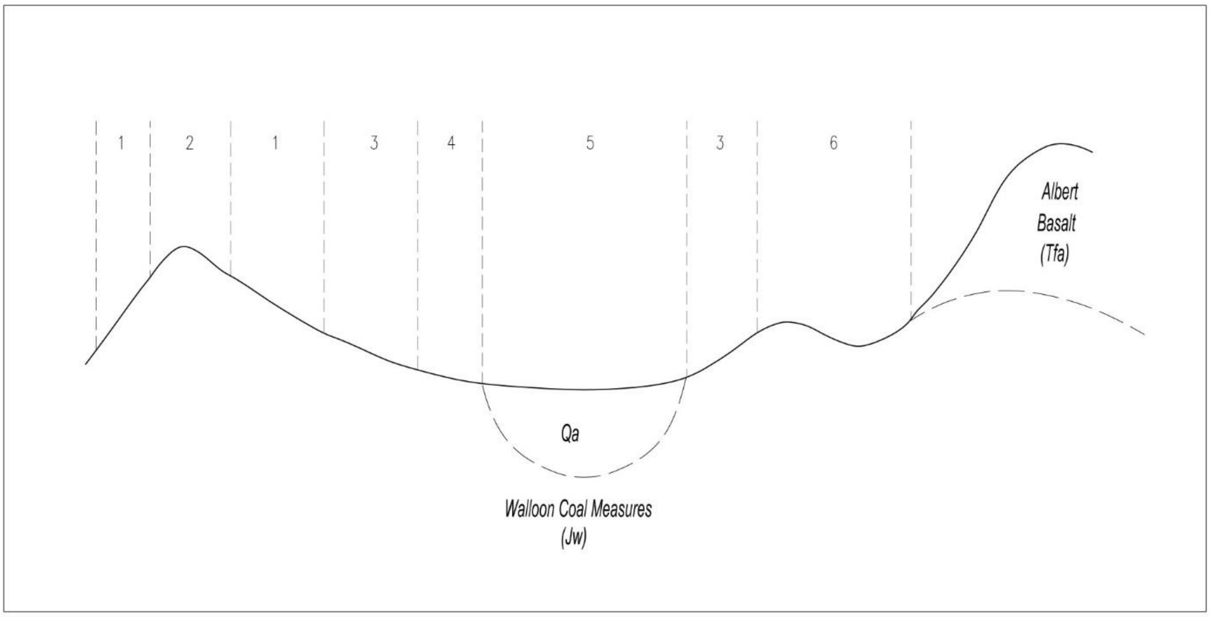
Table 19. Major limitations to agricultural suitability in Walloon Coal Measures landscape 2

Soil Profile Class	Significant agricultural suitability limitations
Josephville (Jo)	Erosion, soil water availability, nutrient deficiency, soil depth.
Nindooinbah Deep Phase (NiDp)	Erosion, soil water availability, slope.
Nindooinbah Acidic Phase (NiAp)	Erosion, soil water availability, slope, pH.
Kagaru (Ka)	Frost.
Bell (SEQ) (Bl)	Frost, flooding, landscape complexity.
Cooeeimbardi (Cb)	Frost, flooding, landscape complexity.
Bremer (B)	Frost, flooding, landscape complexity, wetness.

Figure 42. *Kagaru* and *Lillydale* soil examples. Top row: *Kagaru* soil core and lower slope landscape with basalt hills/mountains in background (Site 690); Bottom row: *Lillydale* soil core and midslope landscape looking east towards basalt and rhyolite hills (Site 691) (note rhyolite outcrops in distance).

9.7.3. Walloon Coal Measures soil and landscape example 3: Nindooinbah

These landscapes are situated on undulating to rolling low hills between the Albert River and Kerry and Cainbable Creeks, and more widely between higher basalt hills at Nindooinbah and Kerry. Shallow to moderately deep Red Chromosols and Kurosols (*Drynan*) are found on crests and upper slopes on the western side while adjacent mid slopes exhibit moderately deep Brown, Yellow and Grey Chromosols (*Brennan* & *Brabazon*). Deeper Black Dermosols (*Edendale*) may be found as slopes reduce and approach the alluvium (on both sides of the landscape) with its deep Black Vertosols (*Blenheim* & *Bell (SEQ)*). On the eastern side as elevations rise again, moderately deep Red and Brown Dermosols (*Nindooinbah*) are found on the slopes below the basalt hills.



Unit	Landform	Soil Description	Soil Profile Class
1	Mid and upper slopes of undulating to steep rises and low hills. Slope 1-20%, but may be up to 35%.	Moderately deep to very deep, grey, frequently bleached, mottled, strongly acidic to neutral, texture contrast soils overlying grey, brown or yellow subsoils on sandstone or siltstone. Subsoils may be sodic and/or mildly to moderately saline. Imperfectly drained.	***Brennan*** **(Be)** (Grey Chromosol or Kurosol)
2	Crests and slopes of undulating to rolling rises or low hills. Slope 0-15%.	Moderately deep (also shallow), red, texture contrast soil on siltstone and sandstone, generally underlain by grey clays. Subsoils are acidic or strongly acidic but may be alkaline and calcic at depth in siltstone saprolite. Poorly to imperfectly drained.	***Drynan*** **(Dn)** (Red Chromosol or Kurosol)
3	Mid and lower slopes of undulating to rolling rises and low hills. Slope 3-15%.	Moderately deep, brown texture contrast soils on siltstone and sandstone from 0.5 m. Subsoils are slightly acidic to alkaline, mottled and occasionally mildly saline and/or vertic. Imperfectly to moderately well drained.	***Brabazon*** **(Bz)** (Brown or Yellow Chromosol)
4	Lower slopes and flats (rarely mid slopes) of undulating to rolling rises and low hills. Slope <15%.	Moderately deep to very deep, neutral to strongly alkaline, black, non-cracking, uniformly fine soils over sandstone or siltstone. Black clay over brown, black or grey, frequently calcic subsoils. May be slightly saline. Imperfectly to moderately well drained.	***Edendale*** **(Ed)** (Black Dermosol)
5	Plains, back plains, fans and terrace plains on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim*** **(Bm)** (Black Vertosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)*** **(Bl)** (Black Vertosol)
6	Slopes (rarely crests or ridges) of undulating to rolling rises to hills. Slopes <20%.	Moderately deep, red or brown, neutral to strongly alkaline non-cracking gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Imperfectly to moderately well drained.	***Nindooinbah*** **(Ni)** (Red or Brown Dermosol)

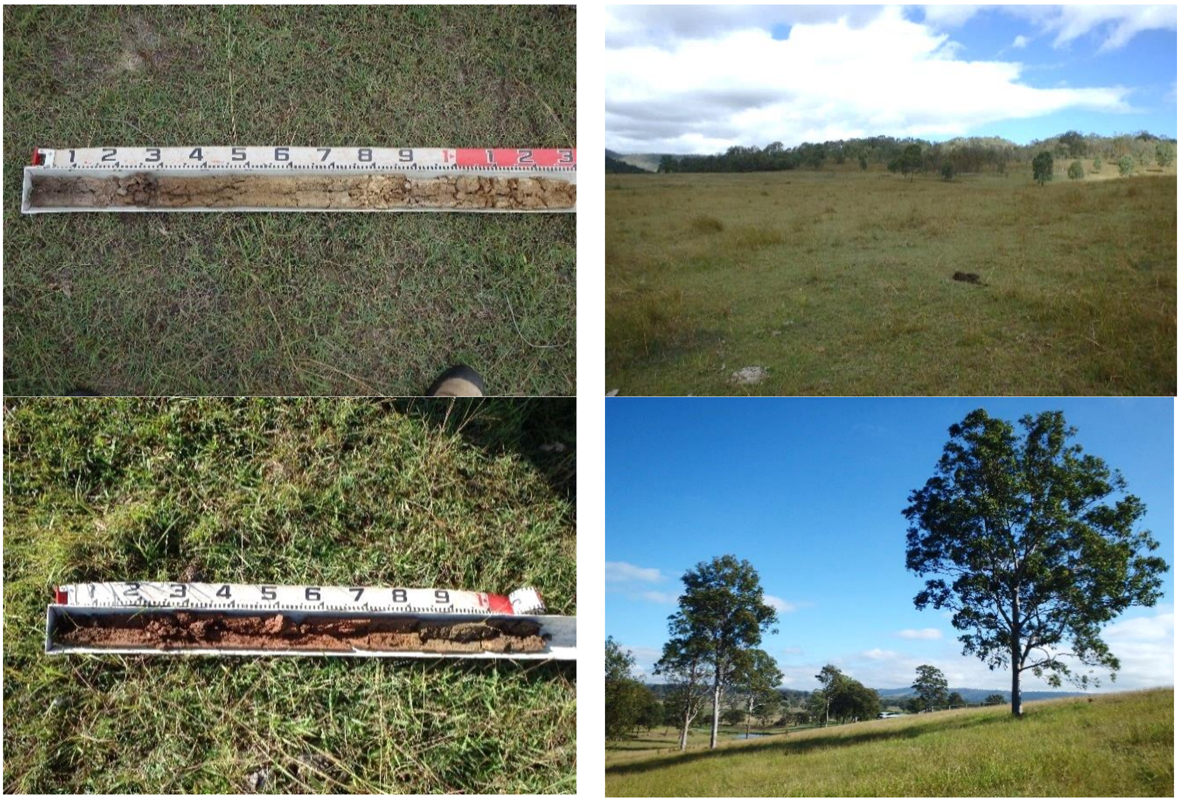


Figure 43. *Brabazon* and *Nindooinbah* soil examples. Top row: *Brabazon* soil core and lower slope landscape (Site 723); Bottom row: *Nindooinbah* (Red Dermosol) soil core and mid slope landscape (Site 2081).

All slopes in these landscapes are currently used for grazing with agricultural land classes of C1 and B. Alluviums are classified as A1 and are currently cultivated or have been in the past. Major limitations to agricultural suitability are listed in Table 20.

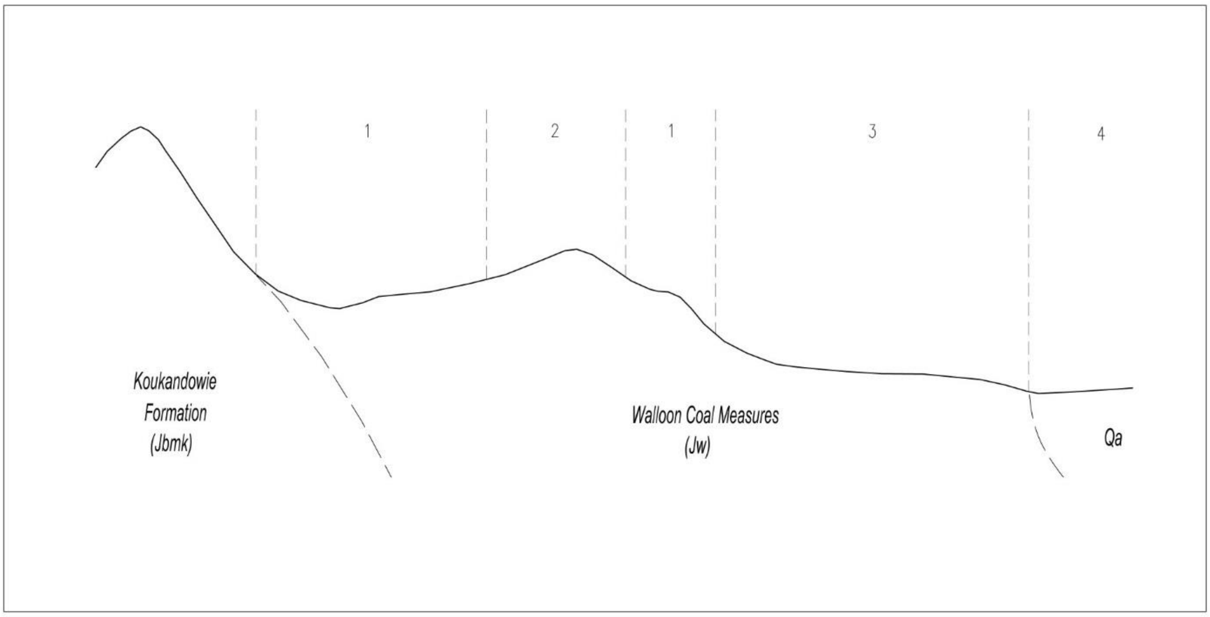
Table 20. Major limitations to agricultural suitability in Walloon Coal Measures landscape 3

Soil Profile Class	Significant agricultural suitability limitations
Brennan (Be)	Erosion, soil water availability, nutrient deficiency, slope, landscape complexity, wetness.
Drynan (Dn)	Erosion, soil water availability, rockiness, landscape complexity.
Brabazon (Bz)	Erosion, soil water availability, nutrient deficiency, wetness.
Edendale (Ed)	Erosion, wetness.
Blenheim (Bm)	Frost, flooding.
Bell (SEQ) (Bl)	Frost, flooding, landscape complexity.
Nindooinbah (Ni)	Erosion, soil water availability, soil depth, landscape complexity, wetness.

9.7.4. Walloon Coal Measures soil and landscape example 4: Laravale/Round Mountain

This landscape is located at Round Mountain and Laravale on undulating to rolling low hills and rises west of the Logan River and east of the higher Koukandowie Formation low hills and hills to the west.

Moderately deep Red or Brown Dermosols (*Nindooinbah*) or Red Chromosols and Kurosols (*Drynan*) occur on crests of low hills and rises. Down slope are deeper Brown and Grey Chromosols (*Laravale*) which in turn grade to moderately deep Brown and Grey Dermosols and Vertosols (*Lillydale* & *Gould*) before the basalt dominant alluvium (*Bell (SEQ))* & *Bremer*) is encountered closer to the Logan River.



Unit	Landform	Soil Description	Soil Profile Class
1	Mid and lower slopes and flats of undulating to rolling rises, low hills and terraces. Slope <20%.	Deep to very deep, brown, black or grey, neutral to strongly alkaline, rarely bleached, texture contrast soils over sandstone and siltstone from 1.0 m. Subsoils are frequently mottled and subsoils may also be mildly saline or sodic. Imperfectly to moderately well drained.	***Laravale*** **(Lv)** (Brown/Grey Chromosol)
2	Crests and slopes of undulating to rolling rises or low hills. Slope <20%.	Moderately deep, red or brown, neutral to strongly alkaline non-cracking gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Imperfectly to moderately well drained.	***Nindooinbah*** **(Ni)** (Red or Brown Dermosol)
		Moderately deep (also shallow), red, texture contrast soil on siltstone and sandstone, generally underlain by grey clays. Subsoils are acidic or strongly acidic but may be alkaline and calcic at depth in siltstone saprolite. Poorly to imperfectly drained.	***Drynan*** **(Dn)** (Red Chromosol or Kurosol)
3	Slopes (rarely broad crests) of undulating and rolling rises and low hills. Slope 2-20%.	Moderately deep to very deep, strongly acidic to neutral, brown, black and grey cracking clay soils on siltstone. Occasionally sodic. Poorly to Moderately well drained.	***Gould*** **(Gd)** (Brown Vertosol, Grey Vertosol)
		Moderately deep to very deep, grey, non-cracking, neutral to alkaline uniformly fine (rarely gradational) clay soils over sandstone and siltstone from 0.9 m. Subsoils are frequently mottled and neutral to strongly alkaline. Subsoils may also be occasionally calcic, slightly to mildly saline or rarely sodic. Poorly to imperfectly drained.	***Lillydale*** **(Ld)** (Grey Dermosol)
4	Plains, back plains, levees, fans and terrace plains on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)*** **(Bl)** (Black Vertosol)
		Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, occasionally mottled, slightly saline and/or vertic. Buried horizons are not encountered within 1.8 m. Imperfectly to moderately well drained.	***Bremer*** **(B)** (Black/Brown/Grey Dermosol)

Much of this landscape is used for grazing, horse breeding and cultivation of fodder to support dairy farming. Agricultural land classes of these landscapes are C1 to A1. Major limitations to agricultural suitability are listed in Table 21.

Table 21. Major limitations to agricultural suitability in Walloon Coal Measures landscape 4

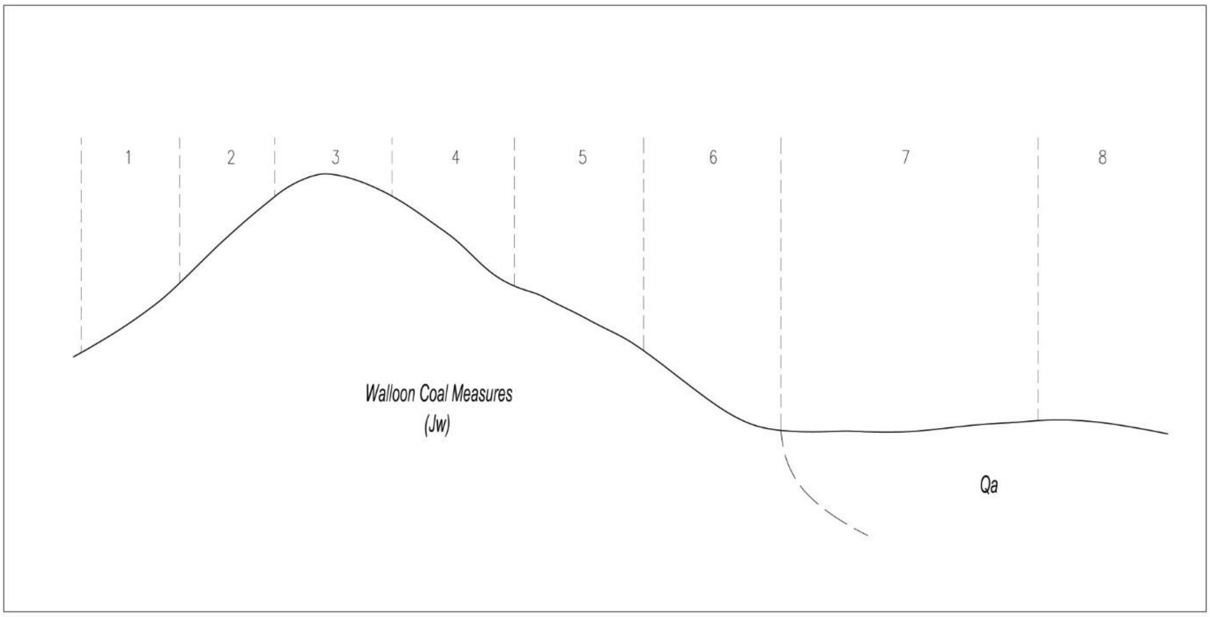
Soil Profile Class	Significant agricultural suitability limitations
Laravale (Lv)	Erosion.
Nindooinbah (Ni)	Erosion, soil water availability, soil depth, landscape complexity, wetness.
Drynan (Dn)	Erosion, soil water availability, rockiness, landscape complexity.
Gould (Gd)	pH.
Lillydale (Ld)	Erosion, nutrient deficiency, drainage.
Bell (SEQ) (Bl)	Frost, flooding, landscape complexity.
Bremer (B)	Frost, flooding, soil water availability, wetness.
Bremer Buried Phase (BBp)	Frost, flooding, landscape complexity, wetness.


Figure 44. *Gould* soil core and dairy cropping on foot slope landscape (Site 618).

9.7.5. Walloon Coal Measures soil and landscape example 5: Cedar Grove

This landscape captures a series of undulating rises (rarely low hills) west of Cedar Grove at the junction of Teviot Brook, Woollaman Creek and the Logan River.

Mid and lower slopes of south or south-eastern facing slopes form deep Brown and Grey Chromosols (*Laravale*) grading to deep Red and Brown Dermosols (*Nindooinbah Deep Phase*) on adjacent upper slopes and shallower Red and Brown Dermosols (*Nindooinbah*) on crests. On northern facing slopes, moderately deep Red Chromosols and Kurosols (*Drynan*) are found on upper slopes, while Brown and Yellow Chromosols (*Brabazon*) occupy the mid slopes. The lower slopes give rise to deep to very deep Black and Brown Vertosols (*Kagaru*) transitioning to the Black, Brown and Grey Vertosols (*Waterford* & *Bell (SEQ)*) of the adjacent alluvial plains and terraces.



Unit	Landform	Soil Description	Soil Profile Class
1	Mid and lower slopes and flats of undulating to rolling rises, low hills and terraces. Slope <20%.	Deep to very deep, brown, black or grey, neutral to strongly alkaline, rarely bleached, texture contrast soils over sandstone and siltstone from 1.0 m. Subsoils are frequently mottled and subsoils may also be mildly saline or sodic. Imperfectly to moderately well drained.	***Laravale* (Lv)** (Brown or Grey Chromosol)
2	Slopes (rarely crests) of undulating to rolling rises to hills. Slopes <25%.	Deep to very deep, red or brown, neutral to strongly alkaline non-cracking uniformly fine (rarely gradational) soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over Walloon sandstone/siltstone from 1.0 m. Moderately well drained.	***Nindooinbah Deep Phase* (NiDp)** (Red or Brown Dermosol)
3	Slopes, crests or ridges of undulating to rolling rises to low hills. Slopes <20%.	Moderately deep, red or brown, neutral to strongly alkaline non-cracking gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Imperfectly to moderately well drained.	***Nindooinbah* (Ni)** (Red or Brown Dermosol)
4	Slopes of undulating to rolling rises or low hills. Slope 0-15%.	Moderately deep (also shallow), red, texture contrast soil on siltstone and sandstone, generally underlain by grey clays. Subsoils are acidic or strongly acidic but may be alkaline and calcic at depth in siltstone saprolite. Poorly to imperfectly drained.	***Drynan* (Dn)** (Red Chromosol or Kurosol)
		As for Drynan with strongly alkaline B22/B23/B3 with calcareous segregations. Moderately well drained.	***Drynan Alkaline Phase* (DnAp)** (Red Chromosol or Kurosol)
5	Mid and lower slopes of undulating to rolling rises and low hills. Slope 3-15%.	Moderately deep, brown texture contrast soils on siltstone and sandstone from 0.5 m. Subsoils are slightly acidic to alkaline, mottled and occasionally mildly saline and/or vertic. Imperfectly to moderately well drained.	***Brabazon* (Bz)** (Brown Chromosol, Yellow Chromosol)
6	Lower slopes and flats of undulating to rolling rises and low hills. Slope 0-15%.	Deep to very deep, brown and black, cracking clay soils on siltstone. Subsoils are alkaline, calcic, commonly mottled, and may also be moderately saline. Imperfectly drained to well drained.	***Kagaru* (Ka)** (Black or Brown Vertosol)
7	Plains and terrace plains on terraces and flood plains.	Deep to very deep, strongly acidic grey, brown and black cracking clays on alluvium. Subsoils are grey, mottled, strongly acidic, and/or occasionally sodic or slightly saline. Buried horizons rarely encountered within 1.8 m. Poorly to imperfectly drained.	***Waterford* (Wa)** (Grey Vertosol, Brown Vertosol, Black Vertosol)
8	Plains, back plains, fans and terrace plains on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)

The majority of the landscape is used for cattle grazing with evidence of past cultivation of some *Bell (SEQ)* soils. Agricultural land classes range from C2/C3 for the slopes to A1 and A2 on alluvial flats. Table 22 lists the limitations to agricultural suitability.

Table 22. Major limitations to agricultural suitability in Walloon Coal Measures landscape 5

Soil Profile Class	Significant agricultural suitability limitations
Laravale (Lv)	Erosion.
Nindooinbah Deep Phase (NiDp)	Erosion, soil water availability, slope.
Nindooinbah (Ni)	Erosion, soil water availability, soil depth, landscape complexity, wetness.
Drynan (Dn)	Erosion, soil water availability, soil depth, rockiness, landscape complexity.
Drynan Alkaline Phase (DnAp)	Erosion, soil water availability, pH, soil depth, landscape complexity.
Brabazon (Bz)	Erosion, soil water availability, nutrient deficiency, wetness.
Kagaru (Ka)	Frost.
Waterford (Wa)	Soil water availability, pH, wetness, frost.
Bell (SEQ) (Bl)	Frost, flooding, landscape complexity.

9.8. Soils and landscapes of the Beaudesert Beds (Te)

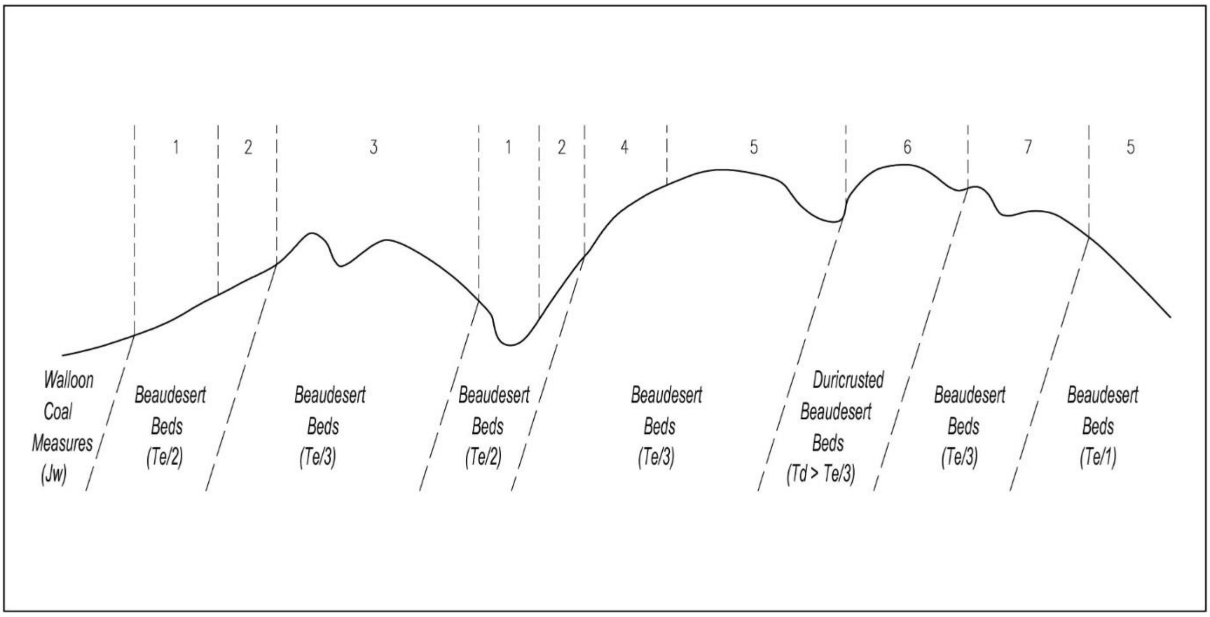
A relatively small landscape and geological unit, the Beaudesert Beds extend from Beaudesert, north to approximately Woodhill and west to Allan Creek. It covers an area of only 3054 hectares of undulating to rolling rises and low hills.

These early Tertiary (Paleocene to Eocene) lacustrine sediments were deposited approximately 43 million years ago and contain a complex range of lithology including carbonaceous mudstone, siltstone, sandstone, conglomerate and basalt. However, as these lithologies are also found in other landscapes, soils here may also be found elsewhere.

Large areas of this unit have been developed for residential and rural residential purposes in areas including Beaudesert to Gleneagle, Versesdale, Woodhill and Cedar Vale. Many other areas remain in agricultural production with major uses including grazing and turf production. Agricultural land classes range from C3 to A1 and D (residential and rural residential). Limitations to agricultural suitability are listed in Table 23. For clarity this unit is shown using the following two soil and landscape examples.

Figure 45. *Laravale* and *Drynan* soil examples. Top row: *Laravale* soil core and lower slope landscape (Site 2218); Bottom row: *Drynan* soil core and broad upper slope landscape (Site 2217)

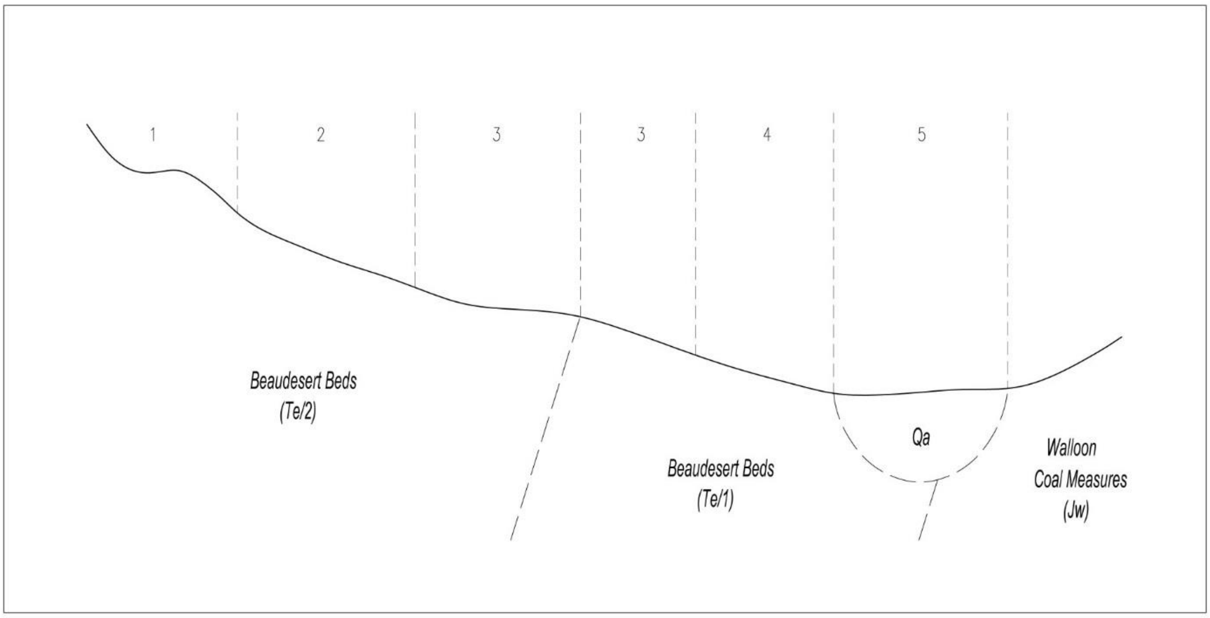
9.8.1. Beaudesert Beds soil and landscape example 1: Veresdale



Unit	Landform	Soil Description	Soil Profile Class
1	Mid and lower slopes and flats of undulating to rolling rises, low hills and terraces. Slope <20%.	Deep to very deep, brown, black or grey, neutral to strongly alkaline, rarely bleached, texture contrast soils over sandstone and siltstone from 1.0 m. Subsoils are frequently mottled and subsoils may also be mildly saline or sodic. Imperfectly to moderately well drained.	***Laravale* (Lv)** (Brown/Grey Chromosol)

Unit	Landform	Soil Description	Soil Profile Class
2	Slopes of undulating to rolling rises or low hills. Slope 1-15%.	Shallow to moderately deep, red, texture contrast soil on siltstone and sandstone, generally underlain by grey clays. Subsoils are acidic or strongly acidic but may be alkaline and calcic at depth in siltstone saprolite. Poorly to imperfectly drained.	***Drynan*** **(Dn)** (Red Chromosol or Kurosol)
3	Crests, ridges, upper and mid slopes of rolling to steep low hills, hills and mountains. Slope 0-40%.	Very shallow to shallow black and brown uniformly fine textured soils over basalt from 0.1 m. Subsoils are neutral and may be saline or very slightly gravelly. Moderately well drained.	***Sarabah*** **(Sa)** (Black or Brown Dermosol)
		Moderately deep, neutral to alkaline, black and brown uniformly fine soils over hard or weathered basalt from 0.6 m. Moderately well drained.	***Tartar Shallow Phase*** **(TtSp)** (Black or Brown Dermosol)
4	Upper slopes of undulating to rolling rises and low hills. Slope 1-15%.	Shallow to moderately deep, red and brown, non-cracking, uniformly fine textured soils. Dark surfaces over occasionally mottled red and brown clays on siltstone from 0.6 m Subsoils may be slightly saline. Moderately well drained to well drained.	***Josephville*** **(Jo)** (Red or Brown Dermosol)
5	Slopes (also crests) of undulating to rolling rises to low hills. Slopes <25%.	Deep to very deep, red or brown, neutral to strongly alkaline non-cracking uniformly fine (rarely gradational) soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 1.0 m. Imperfectly to moderately well drained.	***Nindooinbah Deep Phase*** **(NiDp)** (Red or Brown Dermosol)
		Moderately deep to very deep, red or brown, acidic gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Moderately well drained.	***Nindooinbah Acidic Phase*** **(NiAp)** (Red or Brown Dermosol)
6	Slopes, crests or ridges of undulating to rolling rises to low hills. Slopes generally <20% but may be higher.	Moderately deep, red or brown, neutral to strongly alkaline non-cracking gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Imperfectly to moderately well drained.	***Nindooinbah*** **(Ni)** (Red or Brown Dermosol)
		Moderately deep to very deep, grey, frequently bleached, mottled, strongly acidic to neutral, texture contrast soils overlying grey, brown or yellow subsoils on sandstone or siltstone. Subsoils may be sodic and/or mildly to moderately saline.	***Brennan*** **(Be)** (Grey Chromosol or Kurosol)
7	Slopes of undulating to rolling rises or low hills. Slope 0-15%.	Deep, red, texture contrast soil on siltstone and sandstone, generally underlain by grey clays. Subsoils are acidic or strongly acidic but may be alkaline. Imperfectly drained.	***Drynan Deep Phase*** **(DnDp)** (Red Chromosol or Kurosol)

9.8.2. Beaudesert Beds soil and landscape example 2: Woodhill



Unit	Landform	Soil Description	Soil Profile Class
1	Slopes of undulating to rolling rises or low hills. Slope 1-15%.	Moderately deep (also shallow), red, texture contrast soil on siltstone and sandstone, generally underlain by grey clays. Subsoils are acidic or strongly acidic but may be alkaline and calcic at depth in siltstone saprolite. Poorly to imperfectly drained.	***Drynan* (Dn)** (Red Chromosol or Kurosol)
2	Slopes, crests or ridges of undulating to rolling rises to low hills. Slopes generally <20% but may be higher.	Moderately deep, red or brown, neutral to strongly alkaline non-cracking gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Imperfectly to moderately well drained.	***Nindooinbah* (Ni)** (Red or Brown Dermosol)
3	Mid and lower slopes and flats of undulating to rolling rises, low hills and terraces. Slope <20%.	Deep to very deep, brown, black or grey, neutral to strongly alkaline, rarely bleached, texture contrast soils over sandstone and siltstone from 1.0 m. Subsoils are frequently mottled and subsoils may also be mildly saline or sodic. Imperfectly to moderately well drained.	***Laravale* (Lv)** (Brown or Grey Chromosol)
		Moderately deep, brown texture contrast soils on siltstone and sandstone from 0.5 m. Subsoils are slightly acidic to alkaline, mottled and occasionally mildly saline and/or vertic.	***Brabazon* (Bz)** (Brown or Yellow Chromosol)
4	Lower slopes and flats of undulating to rolling rises and low hills. Slope 0-15%.	Deep to very deep, brown and black, cracking clay soils on siltstone. Subsoils are alkaline, calcic, commonly mottled, and may also be moderately saline. Imperfectly drained to well drained.	***Kagaru* (Ka)** (Black or Brown Vertosol)
		Moderately deep to very deep, strongly acidic to neutral, brown, black and grey cracking clay soils on siltstone. Occasionally sodic. Poorly to Moderately well drained.	***Gould* (Gd)** (Brown Vertosol, Black Vertosol, Grey Vertosol)
5	Plains, back plains, fans and terrace plains on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
	Drainage impaired plains, swamps, drainage depressions and back plains of floodplains and terraces.	Deep to very deep grey cracking clay on alluvium. Subsoils are neutral to alkaline and may be sodic, calcic and/or saline at depth. Poorly to imperfectly drained.	***Basel* (Bs)** (Grey Vertosol, Aquic (Grey) Vertosol, Redoxic Hydrosol)

Table 23. Major limitations to agricultural suitability in Beaudesert Beds landscapes

Soil Profile Class	Significant agricultural suitability limitations
Laravale (Lv)	Erosion.
Nindooinbah Deep Phase (NiDp)	Erosion, soil water availability, slope.
Nindooinbah Acidic Phase (NiAp)	Erosion, soil water availability, slope, pH.
Nindooinbah (Ni)	Erosion, soil water availability, soil depth, landscape complexity, wetness
Drynan (Dn)	Erosion, soil water availability, soil depth, rockiness, landscape complexity.
Drynan Deep Phase (DnDp)	Erosion, soil water availability, landscape complexity.
Josephville (Jo)	Erosion, soil water availability, nutrient deficiency, soil depth.
Sarabah (Sa)	Erosion, soil water availability, soil depth, slope, landscape complexity.
Tartar Shallow Phase (TtSp)	Erosion, soil water availability, soil depth, rockiness, slope, landscape complexity.
Brabazon (Bz)	Erosion, soil water availability, nutrient deficiency, wetness
Brennan (Be)	Erosion, soil water availability, nutrient deficiency, slope, landscape complexity, wetness.
Kagaru (Ka)	Frost.
Gould (Gd)	pH.
Waterford (Wa)	Soil water availability, pH, wetness, frost.
Bell (SEQ) (Bl)	Frost, flooding, landscape complexity.
Basel (Bs)	Permeability and drainage.

9.9. Soils and landscapes of Albert Basalt and Tertiary Volcanics (Tfa/Tv)

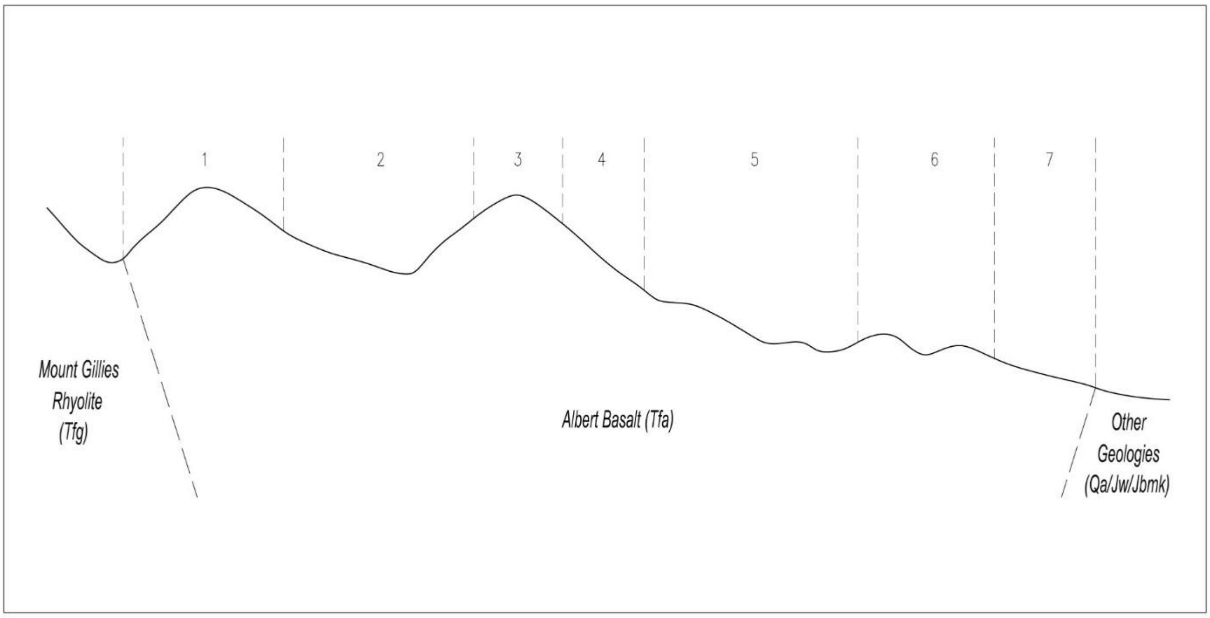
Albert Basalt landscapes formed on these early Miocene (Tertiary) basalts from the Focal Peak volcano (west of Mount Barney) overlie all the older geologies. Lithology is mostly olivine basalt, however, there are also some extrusive rhyolites and sediments deposited between lava flows. Albert Basalts cover almost 53 000 hectares, or 20% of the study area, and take the form of rolling to steep hills and mountains (occasionally low hills) that dominate the south eastern section of the study area.

Soils range from shallow Tenosols (*Sarabah Tenosol Variant*) and Dermosols (*Sarabah* & *Telemon*) on higher, steeper landscapes to moderately deep to very deep Dermosols and Vertosols (*Chinghee, Palen* & *Tartar*) on lower slopes and fans. These basalts have been the largest contributor to the Logan River and Albert River alluviums.

The largely rugged nature of these landscapes means that agricultural land use is predominately grazing on moderate to steep slopes, with improved pasture and cultivation for cropping/fodder confined to lower slopes, fans and benches. Large areas of these basalts are dedicated to forestry or national park/conservation. A number of historic and active quarries are also found on Albert Basalt hills. Agricultural land classes, as would be expected, range from D to A1. The major limitations for each soil are presented in Table 24.

The following two landscape examples demonstrate typical distributions of the many basalt derived soils in these areas.

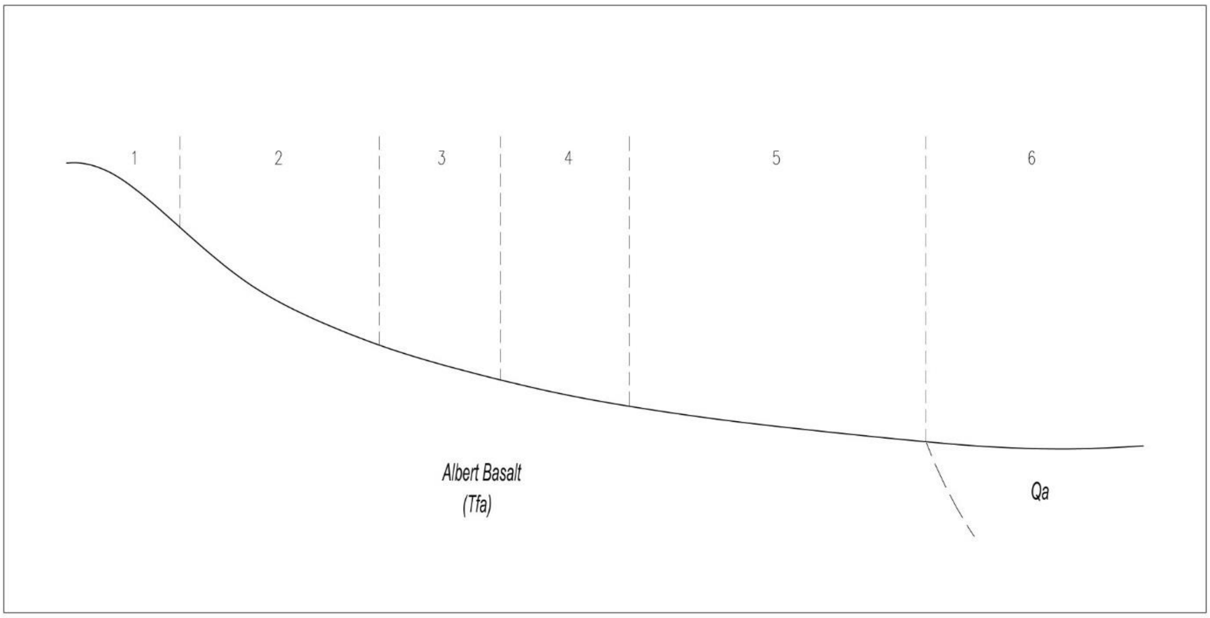
9.9.1. Albert Basalt soil and landscape example 1:



Unit	Landform	Soil Description	Soil Profile Class
1	Crests, ridges, upper and mid slopes of rolling to steep low hills, hills and mountains. Slope 0-40%.	Very shallow to shallow black and brown uniformly fine textured soils over basalt from 0.1 m. Subsoils are neutral and may be saline or very slightly gravelly. Moderately well drained.	***Sarabah* (Sa)** (Black or Brown Dermosol)
		Moderately deep, red, uniformly fine soils. Subsoils are neutral to alkaline and are rarely very slightly gravelly or calcic. Moderately well drained to well drained.	**Telemon (Tm)** (Red Dermosol)
2	Mid and lower slopes, benches, fans and foot slopes of rolling and steep low hills, hills and mountains. Slope 1-25%.	Deep to very deep black and brown, uniformly fine, non-cracking soils over basalt from 1.0m. Subsoils are neutral to alkaline and may be slightly gravelly, vertic and/or calcic. Salinity is rare.	***Tartar* (Tt)** (Black or Brown Dermosol)
		Moderately deep to deep, black or brown, cracking (not self-mulching) soils over basalt. Subsoils are neutral to strongly alkaline and often calcic and/or saline. Imperfectly to moderately well drained.	***Chinghee* (Ch)** (Black or Brown Vertosol, very rarely Grey Vertosol
3	Crests of rolling hills. Slope 1-4%.	Very shallow, black neutral, uniformly fine soils formed on very gentle or gentle basalt hill crests over weathered basalt from 0.3 m. Moderately well drained.	***Sarabah Tenosol Variant* (SaTv)** (Leptic Tenosol)
4	Crests, ridges, upper and mid slopes of rolling to steep low hills, hills and mountains. Slope 0-40%.	Very shallow to shallow black and brown uniformly fine textured soils over basalt from 0.1 m. Subsoils are neutral and may be saline or very slightly gravelly. Moderately well drained.	***Sarabah* (Sa)** (Black or Brown Dermosol)
5	Slopes of rolling low hills to steep mountains. Slope 0.5-30%.	Moderately deep to deep, black or brown, cracking (not self-mulching) soils over basalt. Subsoils are neutral to strongly alkaline and often calcic and/or saline. Imperfectly to moderately well drained.	***Chinghee* (Ch)** (Black, Brown or Grey Vertosol)
6	Crests, ridges, mid and upper slopes of rolling to steep low hills, hills and mountains. Slope 0-30%.	Shallow to moderately deep, neutral to alkaline, black and brown uniformly fine soils over hard or weathered basalt from 0.6 m. Moderately well drained.	***Tartar Shallow Phase* (TtSp)** (Black or Brown Dermosol)
7	Lower slopes, fans, foot slopes and benches of rolling to steep low hills, hills and mountains. Slopes <20%.	Deep to very deep, black, cracking clays on basalt and basalt colluvium. Subsoils are neutral to strongly alkaline, calcic, slightly gravelly and may have salinity at depth. Moderately well drained.	***Palen* (Pa)** (Black or Brown Vertosol, Black Dermosol)
		Very deep black and brown uniformly fine soils. Subsoils are neutral to alkaline and may be slightly gravelly and/or calcic. Salinity is rare.	***Tartar* (Tt)** (Black or Brown Dermosol)

Figure 46. ***Telemon*, *Tartar* and *Chinghee* soil examples. Top row: *Telemon* soil core and upper slope landscape (Site 2171); Middle row: *Tartar* soil core and landscape on upper slope of fan near Widgee Creek at Hillview (Site 658); Bottom row: *Chinghee* soil core and mid slope landscape at Running Creek (Site 442).**

9.9.2. Albert Basalt soil and landscape example 2:



Unit	Landform	Soil Description	Soil Profile Class
1	Crests, ridges, upper and mid slopes of rolling to steep low hills, hills and mountains. Slope 0-40%.	Very shallow to shallow black and brown uniformly fine textured soils over basalt from 0.1 m. Subsoils are neutral and may be saline or very slightly gravelly. Moderately well drained.	***Sarabah* (Sa)** (Black or Brown Dermosol)
2	Upper slopes of undulating and rolling low hills; mid slopes of rolling to steep rises to hills. Slope 3-40%.	Shallow, neutral to alkaline, black and brown cracking clay soils over hard or weathered basalt from 0.3 m. Rarely self-mulching or calcic. Moderately well drained.	***Gorman* (Go)** (Black or Brown Vertosol)
3	Mid and lower slopes of rolling to steep low hills and hills. Slope 2-25%.	Deep to very deep, black (also brown or rarely grey) self-mulching, cracking clay soils over basalt from 1.2 m. Subsoils are neutral to strongly alkaline, very frequently calcic and may be mottled and/or saline. Imperfectly to moderately well drained.	***Lindesay* (Li)** (Black or Brown Vertosol)
4	Mid and lower slopes, benches, fans and foot slopes of rolling and steep low hills, hills and mountains. Slope <25%.	Very deep black and brown uniformly fine soils. Subsoils are neutral to alkaline and may be slightly gravelly, vertic and/or calcic. Salinity is rare. Deep to very deep, black, cracking clays on basalt and basalt colluvium. Subsoils are neutral to strongly alkaline, calcic, slightly gravelly and may have salinity at depth. Moderately well drained.	***Tartar* (Tt)** (Black or Brown Dermosol) ***Palen* (Pa)** (Black or Brown Vertosol, Black Dermosol)
5	Slopes, fans and foot slopes of undulating to steep low hills and hills. Slope <25%.	Very deep, neutral to alkaline, black, self-mulching, cracking clays and calcic subsoils on basalt and basalt colluvium. Moderately well drained. Deep to very deep, black (also brown or rarely grey) self-mulching, cracking clay soils over basalt from 1.2 m. Subsoils are neutral to strongly alkaline, very frequently calcic and may be mottled and/or saline. Imperfectly to moderately well drained.	***Glenapp* (Gp)** (Black Vertosol) ***Lindesay* (Li)** (Black, Brown or Grey Vertosol)
6	Plains, terrace plains, levees and valley flats on flood plains, alluvial plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, slightly to mildly saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well drained or imperfectly drained.	***Bremer Buried Phase* (BBp)** (Black Dermosol, Brown Dermosol, Grey Dermosol)

Unit	Landform	Soil Description	Soil Profile Class
6		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
		Deep to very deep, black, non-cracking uniformly fine clay soils on alluvium. Subsoils are strongly alkaline and calcic at depth overlying alkaline, calcic buried alluvial horizons. Moderately well drained.	***Hooper* (Hr)** (Black Dermosol)

Figure 47. *Sarabah*, *Lindesay* and *Glenapp* soil examples. Top row: *Sarabah* soil core and upper slope landscape below Little Widgee Mountain looking east to low hills on Walloon Coal Measures (Site 699); Middle row: *Lindesay* soil core and lower slope landscape at Running Creek (Site 466); Bottom row: *Glenapp* soil core and landscape on lower slope of a fan at Christmas Creek (Site 651).

Table 24. Major limitations to agricultural suitability in Albert Basalt landscapes

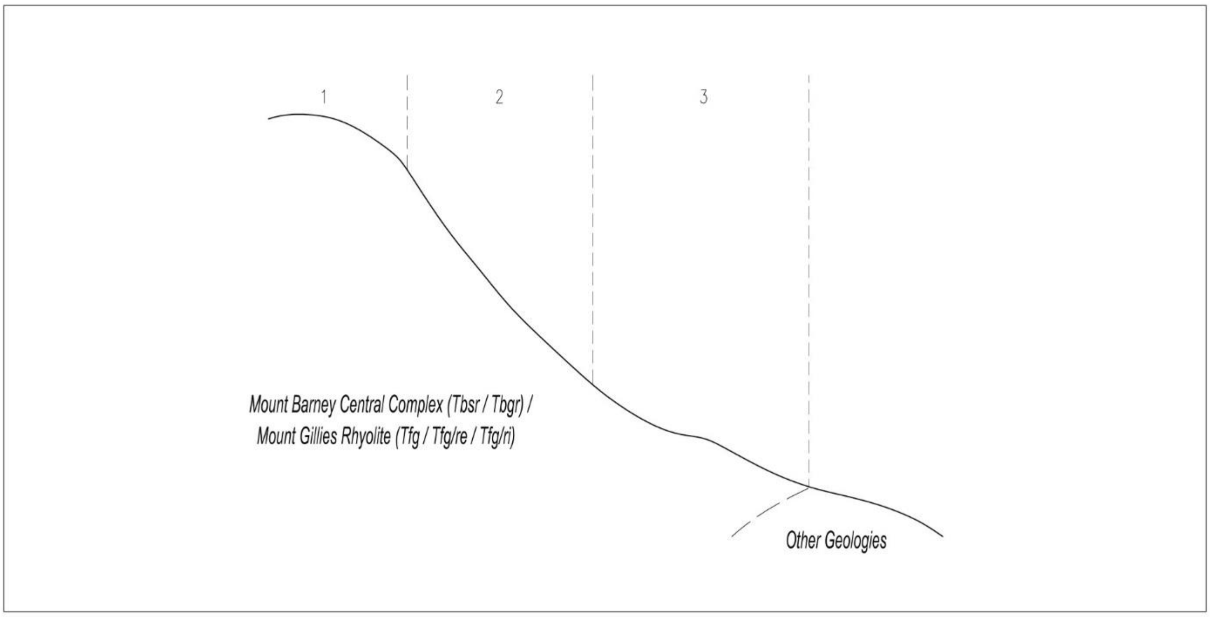
Soil Profile Class	Significant agricultural suitability limitations
Sarabah (Sa)	Erosion, soil water availability, soil depth, rockiness, slope, landscape complexity.
Telemon (Tm)	Erosion, soil water availability, soil depth, rockiness, slope, landscape complexity.
Chinghee (Ch)	Erosion, rockiness, soil water availability, landscape complexity, slope.
Sarabah Tenosol Variant (SaTv)	Soil water availability, soil depth, nutrient deficiency, rockiness, landscape complexity.
Tartar Shallow Phase (TtSp)	Erosion, soil water availability, soil depth, rockiness, slope, landscape complexity.
Palen (Pa)	None significant.
Tartar (Tt)	Erosion, rockiness, salinity, landscape complexity.
Gorman (Go)	Erosion, soil water availability, soil depth, rockiness, slope, landscape complexity.
Lindesay (Li)	Slope, wetness (drainage), landscape complexity.
Glenapp (Gp)	None significant.
Bremer Buried Phase (BBp)	Frost, flooding, wetness.
Bell (SEQ) (Bl)	Frost, flooding.
Hooper (Hr)	Frost, flooding, wetness.

9.10. Soils and landscapes of the Mount Gillies Rhyolite and Mount Barney Central Complex (Tbgr, Tbsr, Tfg)

The early Miocene (Neogene) Mount Gillies Volcanics originated from the Mount Gillies peak eruption approximately 20 million years ago. They appear as Rhyolitic tuffs and flows, acid agglomerate, tuff, minor basalts mostly in the south-west of the study area east of Mount Barney with a few smaller occurrences in the Chinghee Creek area.

The older (Paleogene) Mount Barney Central Complex is also prominent in this part of the study area, primarily in the form of Mount Barney but also as smaller outcrops north-east of Mount Barney and near Mount Barney Creek at Barney View. These granophyre, rhyolite, trachyte, rhyolite intrusions cover approximately 2655 hectares.

Mount Gillies Volcanics and Mount Barney Central Complex produce similar soils due to their largely similar lithology. These are commonly Tenosols (*Barney*) on rolling to steep and very steep hills, although some low hills are present, with deeper Red and Brown Dermosols (*Philp*) on rare lower slopes.



Unit	Landform	Soil Description	Soil Profile Class
1 & 2	Crests and slopes of rolling to very steep rises, low hills, hills and mountains.	Very shallow to moderately deep, uniformly coarse to medium textured, gravelly soils with dark sandy loam to clay loam surfaces over brown and grey sandy clay loams or clay loams, formed on rhyolite. Moderately well drained.	***Barney*** **(Ba)** (Leptic Tenosol, Bleached Leptic Tenosol, Leptic Rudosol)
3	Slopes of hills and low hills. Slopes 3–>30%.	Moderately deep to deep, brown, black or red, strongly acidic to neutral non-cracking clays on rhyolite. Moderately to well drained.	***Philp*** **(Pp)** (Brown Dermosol, Red Dermosol)

Soils in this group are not generally accessible or suitable for agricultural use, however some areas in the upper Logan River at the base of Mount Ernest have been cleared for grazing. Large areas are dedicated to forestry or national park/conservation. As a result the agricultural land class is D with some C3. Major limitations to agricultural suitability are listed in Table 25.

Table 25. Major limitations to agricultural suitability in Neogene rhyolite landscapes

Soil Profile Class	Significant agricultural suitability limitations
Barney (Ba)	Erosion, soil water availability, soil depth, nutrient deficiency, rockiness, slope, landscape complexity.
Philp (Pp)	Erosion, slope, pH, soil depth, rockiness, landscape complexity.

Figure 48. *Barney* soil examples. Top row: *Barney* soil profile and crest landscape with large rhyolite boulders (Site 273) in the upper Logan River valley; Bottom row: *Barney* soil profile and mid slope landscape position (centre of photo) at base of Mount Ernest (Site 284).

9.11. Soils and landscapes of the Beechmont and Hobwee Basalts (Tlb, Tlh)

The early to late Miocene Beechmont and Hobwee Basalts originate from the Mount Warning centred volcano south-east of the study area and their age is younger, or similar to, the Albert Basalt and the Mount Gillies Volcanics. These basalt lava flows differ from the Albert Basalt in that they were purely olivine basalt without rhyolite or tuff and may have been ejected as recently as 8 million years ago.

These landscapes occupy approximately 25 000 hectares of this study area and span an area from the south-east corner of the survey area to Tamborine Mountain along the eastern boundary.

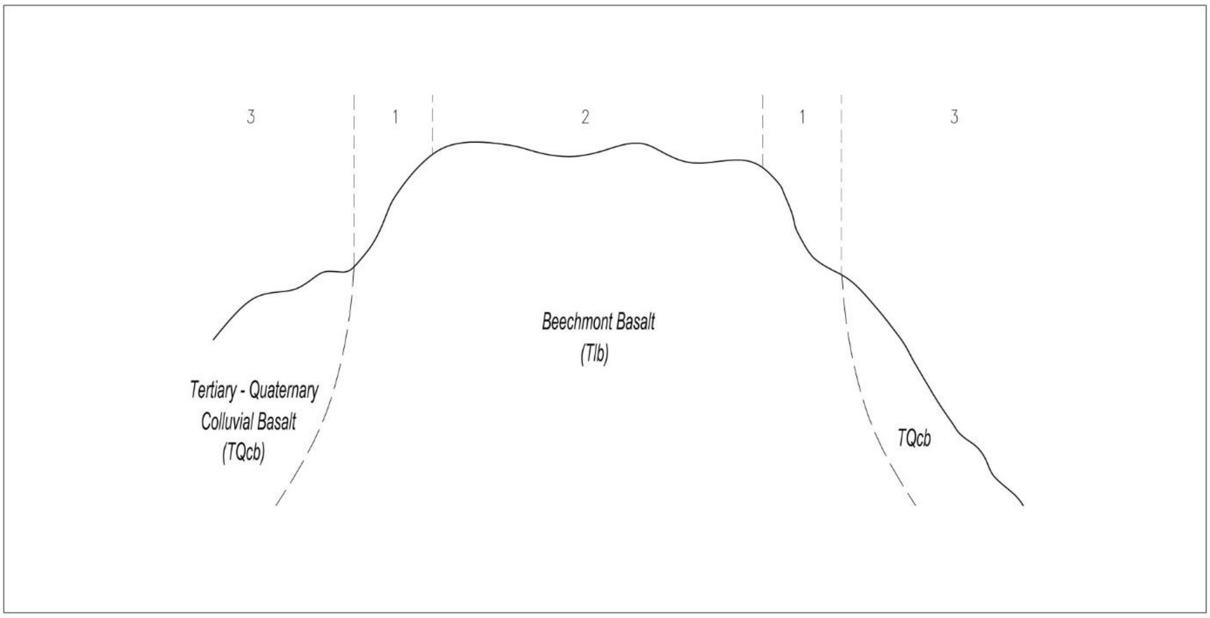
All of these landscapes are elevated, on rolling hills to steep mountains, and are often inaccessible, consequently land use is largely dedicated to forestry or national park/conservation and not agriculture. It follows then that the dominant agricultural land class is D, with very small areas of C3. An exception is the Mount Tamborine plateau where small scale farming has been a feature for many years - its agricultural land class is A2. Limitations to agricultural suitability are listed in Table 26.

The following two landscape examples demonstrate the likely distribution of Beechmont and Hobwee Basalt derived soils in these areas.

9.11.1. Beechmont and Hobwee Basalt soil and landscape example 1: Tamborine Mountain

The majority of the plateau is covered by deep Red Ferrosols and Dermosols (*Tamborine*) while the steep side slopes exhibit much shallower Black, Red and Brown Dermosols (*Cainbable*). Further down slope basalt colluvium (TQcb) has been deposited, forming slightly gentler gradients where

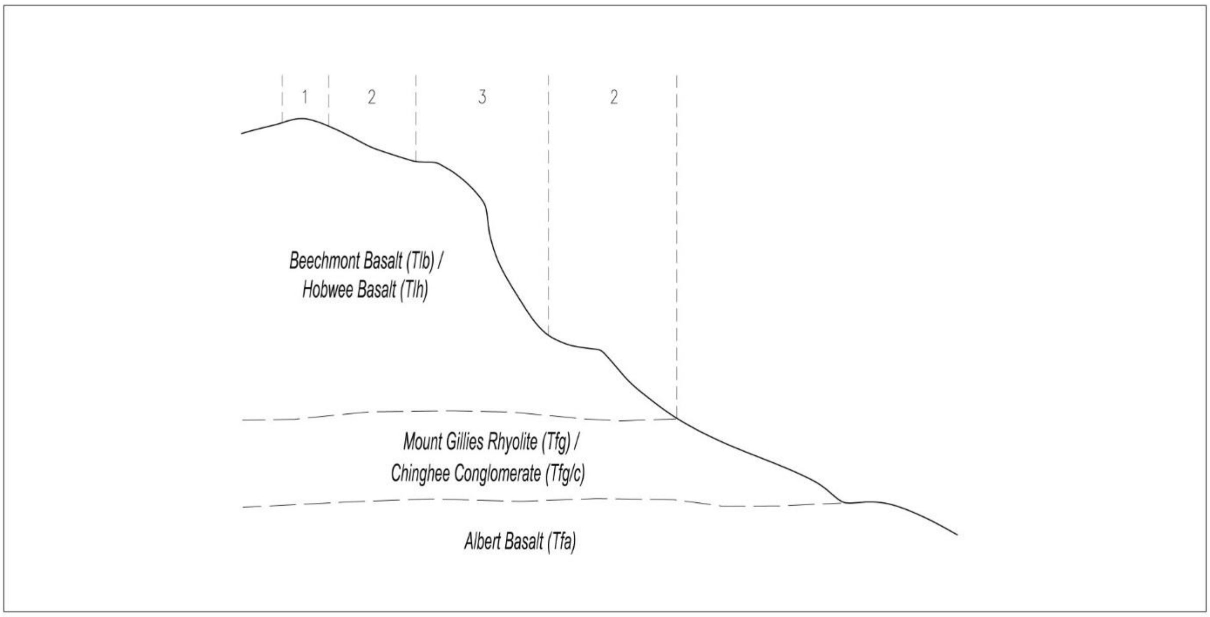
Black and Brown Dermosols and Vertosols (*Wonglepong*) of various depths, dependent upon presence of basalt stones and boulders, can be found.



Unit	Landform	Soil Description	Soil Profile Class
1	Crests and ridges of rolling to steep hills and mountains. Slopes 3 to >50%.	Very shallow to moderately deep, black and red (rarely brown), non-cracking, uniformly fine soils over basalt from 0.2 m. Subsoils range from acidic to neutral. Moderately well drained.	***Cainbable* (Ce)** (Black Dermosol, Red Dermosol, Brown Dermosol)
2	Crests and slopes of undulating to steep rises and low hills. Slope 0.5-15%.	Deep to very deep red, acidic to neutral, uniformly fine soils high in free iron oxide. Non-saline. Moderately well to well drained.	***Tamborine* (Ta)** (Red Ferrosol, Red Dermosol)
3	Slopes of rolling to steep hills and mountains. Slope 4->>20%.	Shallow to moderately deep, black, cracking and non-cracking clays over basalt colluvium or basalt rock from 0.75 m. Subsoils are neutral to strongly alkaline and may be saline or calcic at depth. Moderately well drained.	***Wonglepong* (Wo)** (Black Vertosol, Black or Brown Dermosol)

9.11.2. Beechmont and Hobwee Basalt soil and landscape example 2: Chinghee Creek

Very shallow, clayey Tenosols (*Sarabah Tenosol Variant*) can be found on narrow crests at the highest elevations here grading into gentle to moderately inclined slopes and benches where moderately deep Black Dermosols (*Wonglepong*) have formed. Where the landscape elevation drops rapidly and slopes increase from gentle to very steep, much shallower Black, Red and Brown Dermosols (*Cainbable*) exist directly over basalt rock before changing back to the deeper *Wonglepong* on lower benches and mid slopes above other, older geologies.



Unit	Landform	Soil Description	Soil Profile Class
1	Crests of rolling hills. Slope 1-4%.	Very shallow, black neutral, uniformly fine soils formed on very gentle or gentle basalt hill crests over weathered basalt from 0.3 m. Moderately well drained.	***Sarabah Tenosol Variant* (SaTv)** (Leptic Tenosols)
2	Slopes, benches and valley flats of rolling to steep hills and mountains. Slope 0.5-20%.	Shallow to moderately deep, black, cracking and non-cracking clays over basalt colluvium or basalt rock from 0.75 m. Subsoils are neutral to strongly alkaline and may be saline or calcic at depth. Imperfectly to moderately well drained.	***Wonglepong* (Wo)** (Black Dermosol)
3	Crests and ridges of rolling to steep hills and mountains. Slopes 3 to >50%.	Very shallow to moderately deep, black and red (rarely brown), non-cracking, uniformly fine soils over basalt from 0.2 m. Subsoils range from acidic to neutral. Moderately well drained.	***Cainbable* (Ce)** (Black Dermosol, Red Dermosol, Brown Dermosol)

Table 26. Major limitations to agricultural suitability in Hobwee Basalt and Beechmont Basalt landscapes

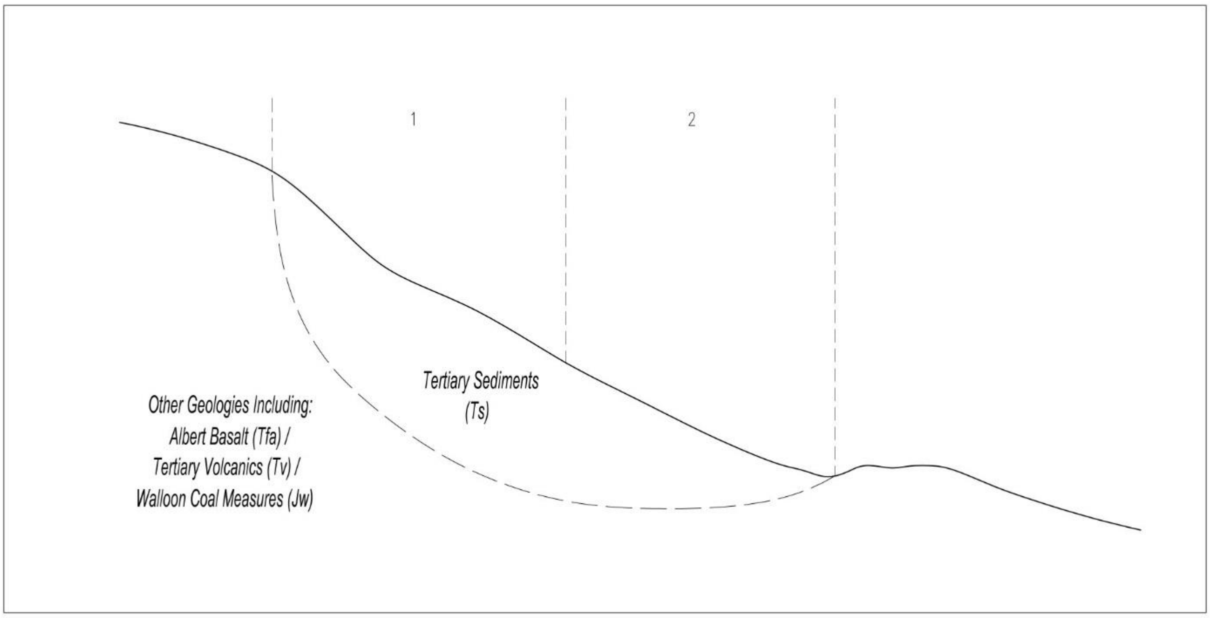
Soil Profile Class	Significant agricultural suitability limitations
Cainbable (Ce)	Erosion, soil water availability, soil depth, rockiness.
Tamborine (Ta)	pH, landscape complexity.
Wonglepong (Wo)	Erosion, soil water availability, soil depth, rockiness, slope, landscape complexity.
Sarabah Tenosol Variant (SaTv)	Soil water availability, soil depth, nutrient deficiency, rockiness, landscape complexity.

Figure 49. *Cainbable* and *Wonglepong* soil examples. Top row: *Cainbable* soil profile and ridge crest landscape (Site 2053); Bottom row: *Wonglepong* soil profile and bench landscape-both at Upper Widgee Creek.

9.12. Soils and landscapes of the Tertiary Sediments (Ts)

These Neogene sediments are isolated, small in area (a total of 540 hectares) and located along the eastern slopes of the Birnam Range, near Mount Dunsinane, with another small area at Kerry.

Lithology includes quartzose to sublabile sandstone, claystone, conglomerate and minor olivine basalt. Upper to mid slopes contain Red and Brown Dermosols and Kandosols (*Dunsinane*) while Brown and Yellow Chromosols and Kurosols (*Brabazon* & *Brabazon Acidic Phase*) occupy the mid to lower slope of these landscapes.



Unit	Landform	Soil Description	Soil Profile Class
1	Slopes of undulating to rolling rises and low hills. Slopes 3-25%.	Shallow to moderately deep, slightly acidic to neutral, occasionally mottled, brown and red gradational and uniformly fine soils on siltstone, mudstone and sandstone from 0.3 m. Subsoils may be sodic. Moderately well drained to well drained.	***Dunsinane* (Ds)** (Brown or Red Dermosol, Brown Kandosol)
2	Mid and lower slopes (occasionally upper slopes and ridges) of undulating to rolling rises and low hills. Slope 3-15%.	Moderately deep, brown texture contrast soils on siltstone and sandstone from 0.5 m. Subsoils are slightly acidic to alkaline, mottled and occasionally saline and/or vertic. Imperfectly to moderately well drained.	***Brabazon* (Bz)** (Brown Chromosol, Yellow Chromosol)
		As for Brabazon with B horizon pH <5.5.	***Brabazon Acidic Phase* (BzAp)** (Brown Kurosol)

Table 27. Major limitations to agricultural suitability in Tertiary Sediments landscapes

Soil Profile Class	Significant agricultural suitability limitations
Dunsinane (Ds)	Erosion, soil water availability, soil depth, nutrient deficiency, rockiness, slope, landscape complexity.
Brabazon (Bz)	Erosion, soil water availability, nutrient deficiency, drainage.
Brabazon Acidic Phase (BzAp)	Erosion, soil water availability, pH, nutrient deficiency, drainage.

Figure 50. *Brabazon* soil examples. Top row: *Brabazon* soil core and mid slope landscape at Oaky Creek (Site 497); Bottom row: *Brabazon Acidic Phase* soil core and lower slope landscape at Kerry (Site 732).

Land use is almost exclusively grazing with a small area of potential cultivation south-east of Beaudesert. Agricultural land class ranges from C2 to C3 to D. Table 27 shows the limitations to their agricultural suitability.

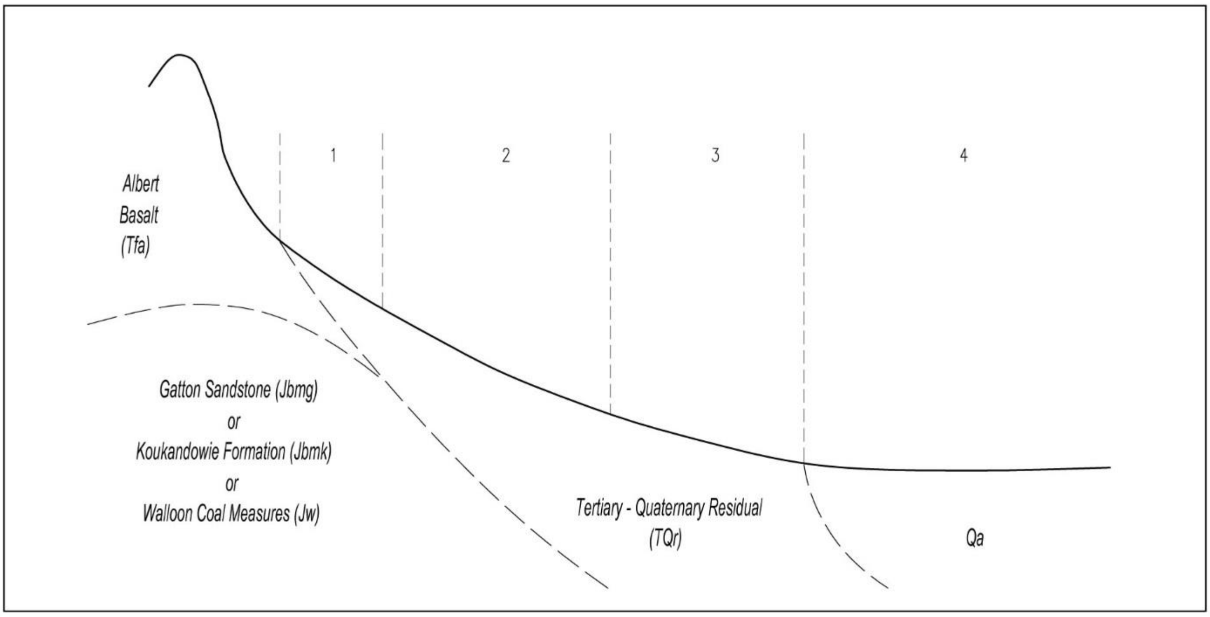
9.13. Soils and landscapes of the Tertiary-Quaternary residuals (TQr)

This group of Miocene/Pliocene (late Tertiary) to Pleistocene colluvial deposits of clay, silt, sand, gravel and soil, generally on older land surfaces, covers approximately 1821 ha, in small scattered areas.

There are three main geological sources of colluvium: basalt at Tabragalba, Oaky Creek and Hillview, rhyolite and sandstone in the upper Logan, Mount Lindesay and Palen Creek, Walloon Coal Measures and Neranleigh-Fernvale Beds derived siltstone and greenstone at Tabragalba and Cedar Creek in the north-east of the study area. The following three diagrams show the relationships between landscape and soils in these distinct areas.

9.13.1. Tertiary-Quaternary residuals soil and landscape example 1: Basalt deposits at Tabragalba, Oaky Creek and Hillview

Upper extents of footslopes and fans exhibit Black Vertosols and Dermosols (*Wonglepong* & *Palen*) of various depths, while mid slopes have very deep, calcic black Vertosols and Dermosols (*Palen*). Self-mulching, very deep black Vertosols (*Glenapp*) occupy lower slopes before grading into deep black alluvial Vertosols (*Blenheim, Bell (SEQ)* or *Cooeeimbardi*) on adjacent alluvial plains or terraces.

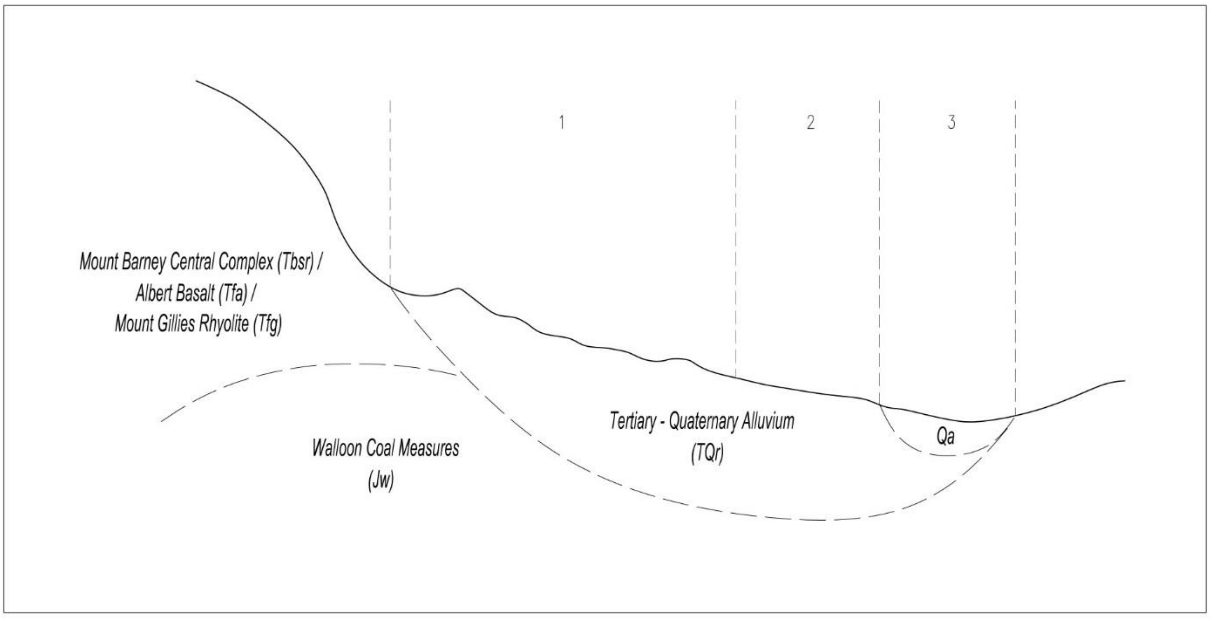


Unit	Landform	Soil Description	Soil Profile Class
1	Slopes of rolling to steep hills and mountains. Slope 4->>20%.	Shallow to moderately deep, neutral to strongly alkaline, black cracking and non-cracking clays over basalt colluvium from 0.75 m. Subsoils are alkaline or strongly alkaline and may be slightly saline or calcic at depth. Moderately well drained.	***Wonglepong*** **(Wo)** (Black Vertosol, Black or Brown Dermosol)
	Lower slopes, fans, foot slopes and benches of rolling to steep low hills and hills. Slopes <20%.	Deep to very deep, black, cracking clays on basalt and basalt colluvium. Subsoils are neutral to strongly alkaline, calcic, slightly gravelly and may have salinity at depth. Moderately well drained.	***Palen*** **(Pa)** (Black Vertosol, Black or Brown Dermosol)
2	Lower slopes, fans, foot slopes and benches of rolling to steep low hills and hills. Slopes <20%.	Deep to very deep, black, cracking clays on basalt and basalt colluvium. Subsoils are neutral to strongly alkaline, calcic, slightly gravelly and may have salinity at depth. Moderately well drained.	***Palen*** **(Pa)** (Black Vertosol, Black or Brown Dermosol)
3	Lower slopes, fans and footslopes of undulating and rolling low hills and hills. Slope <15%.	Very deep, neutral to alkaline, black, self-mulching, cracking clays and calcic subsoils on basalt and basalt colluvium. Moderately well drained.	***Glenapp*** **(Gp)** (Black Vertosol)
4	Plains, terrace plains and valley flats on	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at	***Blenheim*** **(Bm)** (Black Vertosol)

	alluvial/flood plains and terraces.	depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)*** **(Bl)** (Black Vertosol)
		Deep to very deep self-mulching, neutral to alkaline, black cracking clay soils on alluvium. Subsoils are not calcic, rarely mottled and may be slightly saline. Moderately well drained.	***Cooeeimbardi*** **(Cb)** (Black Vertosol)

9.13.2. Tertiary-Quaternary residuals soil and landscape example 2: Rhyolite and sandstone deposits in the upper Logan

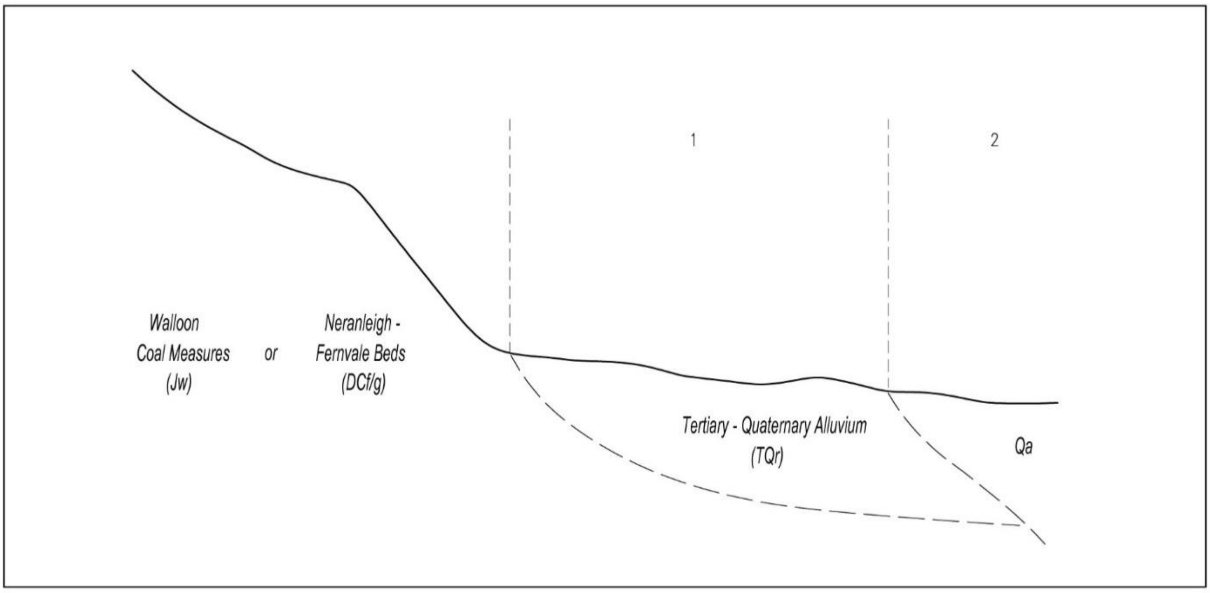
Imperfectly drained and moderately deep grey soils (*Ernest*) can be found in the upper section of these fans and lower slopes, while deeper brown and Black Dermosols (*Shaws*), still with imperfect drainage, are located on the lower portions. These lower slopes grade into deep alluvium of various origins (*Bremer* and *Monsildale*).



Unit	Landform	Soil Description	Soil Profile Class
1	Mid and lower slopes and fans on rolling to steep low hills, hills and mountains. Slope 3-20%.	Moderately deep to deep, acidic to neutral, frequently bleached, grey gradational and uniformly fine soils. Subsoils are commonly mottled, slightly gravelly and may be alkaline at depth. Sandstone or rhyolite present from 0.9 m. Imperfectly drained.	***Ernest*** **(Er)** (Grey Dermosol, Grey Kurosol)
2	Lower slopes and fans on rolling low hills and hills. Slope 1-15%.	Deep to very deep, black, frequently mottled, uniformly fine soils formed on colluvium. Surfaces are black and subsoils are neutral to alkaline and may be very slightly gravelly and/or saline and rarely calcic. Imperfectly drained.	***Shaws*** **(Sh)** (Black Dermosol, Brown Dermosol)
3	Plains, terrace plains, levees and fans on alluvial plains, plains, flood plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, occasionally mottled, slightly saline and/or vertic. Buried horizons are not encountered within 1.8 m. Imperfectly to moderately well drained.	***Bremer*** **(B)** (Black or Brown or Grey Dermosol)
		Deep to very deep, neutral black or brown gradational soils on alluvium. Black clay loams over black and brown clays. Subsoils are neutral, weakly to moderately structured clays over buried horizons. Moderately well drained.	***Monsildale*** **(Mn)** (Black Dermosol, Brown Dermosol)
		Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well drained or imperfectly drained.	***Bremer Buried Phase*** **(BBp)** (Black Dermosol, Brown Dermosol, Grey Dermosol)

9.13.2.1. Tertiary-Quaternary residuals soil and landscape example 3: Walloon Coal Measures and Neranleigh-Fernvale Beds derived siltstone and greenstone at Tabragalba and Cedar Creek

On these much gentler slopes, deep Black and Brown Dermosols (*Shaws*) with imperfect drainage can be found only slightly elevated above the adjoining alluvial plains, fans and terraces which support a range of deep to very deep Black, Brown and Grey Dermosols and Vertosols (*Blenheim, Bell (SEQ), Bremer* and *Spencer*).



Unit	Landform	Soil Description	Soil Profile Class
1	Lower slopes and fans on rolling low hills and hills. Slope 1-15%.	Deep to very deep, black, frequently mottled, uniformly fine soils formed on colluvium. Surfaces are black and subsoils are neutral to alkaline and may be very slightly gravelly and/or saline and rarely calcic. Imperfectly drained.	***Shaws* (Sh)** (Black Dermosol, Brown Dermosol)
2	Plains, terrace plains, levees and fans on alluvial plains, plains, flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim* (Bm)** (Black Vertosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
		Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, occasionally mottled, slightly saline and/or vertic. Buried horizons are not encountered within 1.8 m. Imperfectly to moderately well drained.	***Breme*r (B)** (Black or Brown or Grey Dermosol)
		Deep to very deep, neutral to alkaline, grey or brown, sodic, texture-contrast soil, with frequent bleach on alluvium. Subsoil is mottled and occasionally slightly saline at depth. Poorly to imperfectly drained.	***Spencer* (Sp)** (Grey Sodosol, Brown Sodosol)

Land uses range from cropping (or past cropping) on basalt derived soils at Tabragalba, Christmas Creek (at Hillview) and Oaky Creek and greenstone derived soils at Cedar Creek (agricultural land class A1 or A2) to grazing, forestry and national parks on the remainder (agricultural land class C1, C2, C3, or D). Limitations to agricultural suitability in these landscapes are listed in Table 28.

Table 28. Major limitations to agricultural suitability in TQr landscapes

Soil Profile Class	Significant agricultural suitability limitations
Wonglepong (Wo)	Erosion, rockiness, slope, landscape complexity.
Palen (Pa)	Erosion, rockiness, soil adhesiveness.
Glenapp (Gp)	Soil adhesiveness.
Ernest (Er)	Erosion, soil water availability, nutrient deficiency, rockiness.
Shaws (Sh)	Frost, erosion, soil adhesiveness.

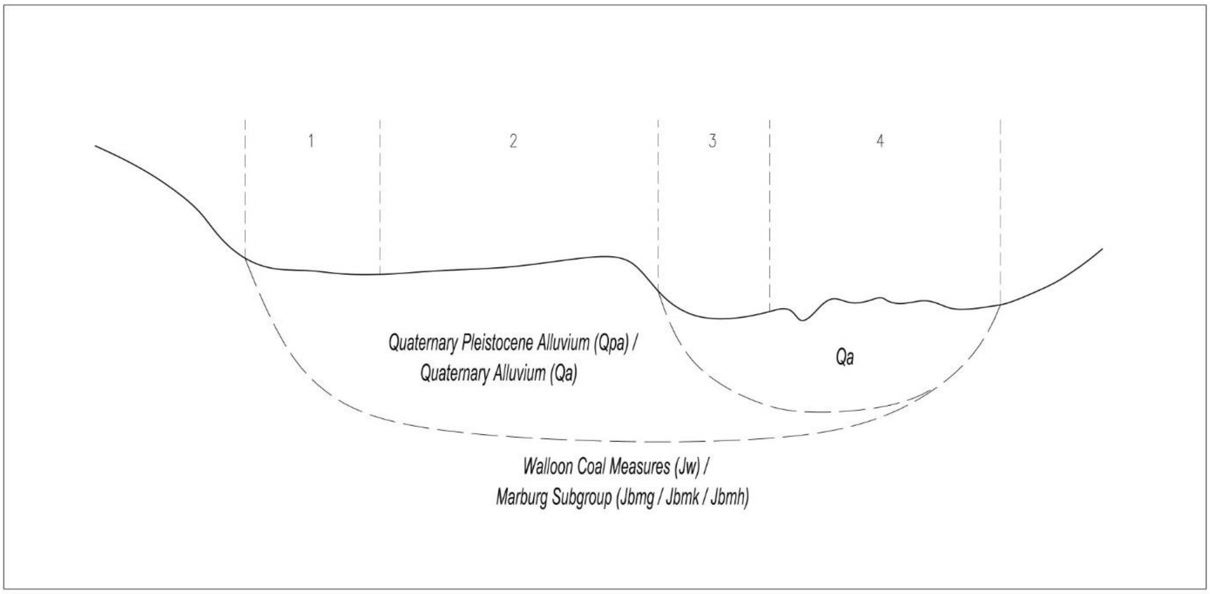
Figure 51. *Glenapp*, *Palen* and *Shaws* soil examples. Top row: *Glenapp* soil core and lower slope of fan landscape with dairy fodder under centre pivot irrigation at Hillview (Site 675); Middle row: *Palen* soil core and upper foot slope landscape at Mount Alexander on the Albert River (Site 2060); Bottom row: *Shaws* soil core and lower slope/fan landscape at Tabragalba, note gully erosion in foreground (Site 757).

9.14. Soils and landscapes of the Quaternary (Pleistocene to Holocene) Alluvium

The following landscape concepts show the locations of the 30 alluvial soil types (SPC's) adjacent to the major creeks and rivers covering approximately 13% of the study area. These have been split into eight diagrams representing various parts of the Logan and Albert River catchment and the differing materials from which they are derived.

9.14.1. Quaternary alluvium soil and landscape example 1: Teviot Brook at Kagaru

Alluvial materials in this area have come from a number of sources including Woollaman Creek and Teviot Brook that flow through Gatton Sandstone hills, while local deposition from Walloon Coal Measures is also likely to have occurred. Clay rich materials from further upstream in Teviot Brook may also be present.



Unit	Landform	Soil Description	Soil Profile Class
1	Plains and terrace plains on terraces and flood plains.	Deep to very deep, strongly acidic grey, brown and black cracking clays on alluvium. Subsoils are grey, mottled, strongly acidic, and/or occasionally sodic or slightly saline. Buried horizons rarely encountered within 1.8 m. Poorly to imperfectly drained.	***Waterford*** **(Wa)** (Grey Vertosol, Brown Vertosol, Black Vertosol)
2	Plains and terrace plains on flood plains and terraces. Slopes 0-2.5%.	Deep to very deep, brown, sporadically or conspicuously bleached, cracking (not self-mulching) clay soils on alluvium. Subsoils are acidic and frequently mottled. Poorly drained.	***Bridge*** **(Br)** (Brown Vertosol, Grey Vertosol)
3	Plains and terrace plains on level to undulating alluvial and flood plains and terraces.	Deep to very deep, brown, neutral texture contrast soils formed on alluvium. Commonly bleached loamy surfaces over neutral, frequently mottled brown and grey clays. Imperfectly to moderately well drained.	***Kilmoylar*** **(Km)** (Brown Chromosol, Yellow Chromosol)
4	Terraces, plains, fans and valley flats of level to gently undulating plains and flood plains. Slope <5%.	Deep to very deep soils with a very strong texture contrast between A and B horizons formed on sandstone and siltstone influenced alluvium. Frequently bleached, grey and black sandy to clay loamy surfaces over mottled, slightly acidic to alkaline, often sandy, grey clays. Buried alluvial horizons are common. Poorly to imperfectly drained.	***Beausang*** **(Bg)** (Grey Chromosol, Grey Sodosol)

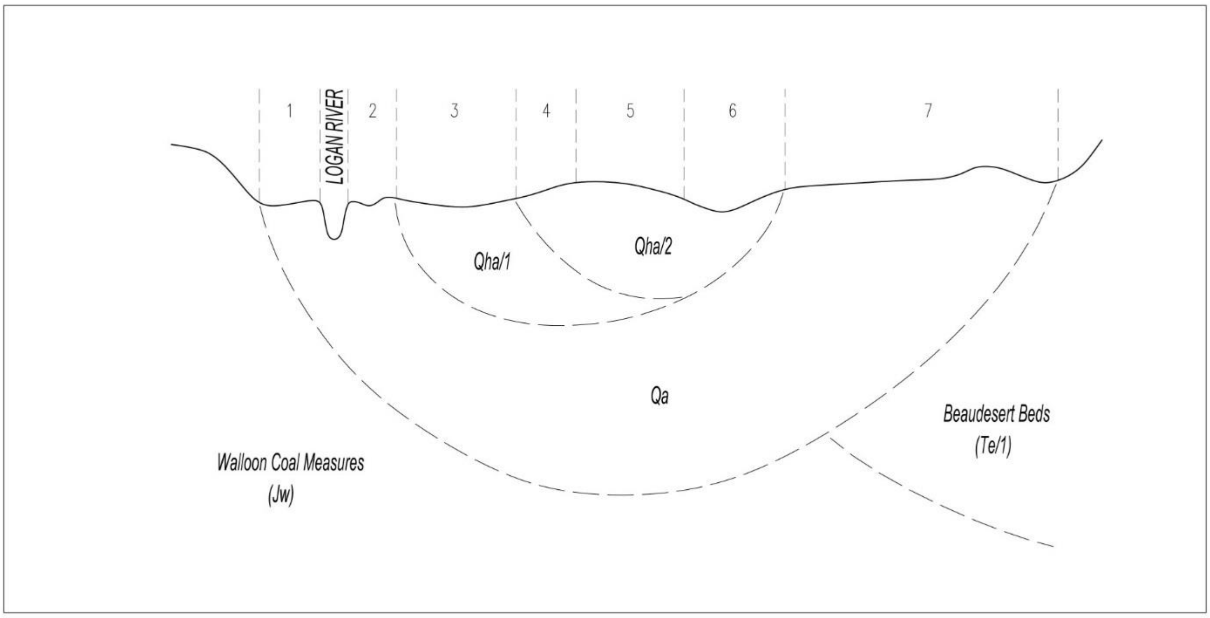
Land use is heavily dependent upon the soil type and as the majority are poorly drained or acidic (*Waterford, Bridge* and *Beausang* soils), grazing is dominant. Agricultural land class ranges from C2 to C1, with some A2 and rarely A1. Limitations to agricultural suitability are listed in Table 29.

Table 29. Major limitations to agricultural suitability in Quaternary Alluvium landscape example 1

Soil Profile Class	Significant agricultural suitability limitations
Waterford (Wa)	Soil water availability, pH, wetness, frost.
Bridge (Br)	Soil adhesiveness, frost, soil water availability, wetness.
Kilmoylar (Km)	Frost, flooding.
Beausang (Bg)	Wetness, soil water availability.

9.14.2. Quaternary alluvium soil and landscape example 2: Logan River at Cedar Grove

Soils in this area are dominated by basalt sediments from upstream in the Logan River catchment producing productive deep Black Vertosols (*Blenheim* & *Bell (SEQ)*) on alluvial plains. However, there are also more poorly drained to acidic Vertosols (*Waterford, Basel* & *Payne*) on plains swamps and back plains. These landscapes also show some sandstone/siltstone influence from Walloon Coal Measures and Beaudesert Beds geologies expressed in the form of poorly drained, sodic or saline Chromosols and Sodosols (*Beausang*, *Sippel* & *Spencer*).



Unit	Landform	Soil Description	Soil Profile Class
1	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim* (Bm)** (Black Vertosol)
2	Terraces, plains, fans and valley flats of level to gently undulating plains. Slope <5%.	Deep to very deep texture contrast soils with a very strong texture contrast between A and B horizons formed on sandstone and siltstone influenced alluvium. Frequently bleached. Poorly to imperfectly drained.	***Beausang* (Bg)** (Grey Chromosol, Grey Sodosol)
3	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
4	Plains, terrace plains, levees and channel benches on flood plains and terraces.	Deep to very deep brown and grey strong texture contrast soils. Sandy loam and clay loam surfaces over sandy clay loam to medium heavy clay. Subsoils are neutral to alkaline and occasionally calcic and/or mottled, saline or sodic at depth. Poorly to moderately well drained.	***Sippel* (Sl)** (Brown Chromosol, Grey Chromosol)

Unit	Landform	Soil Description	Soil Profile Class
4	Plains and terrace flats on alluvial and flood plains and terraces.	Deep to very deep, neutral to alkaline, grey or brown, sodic, texture-contrast soil, with frequent bleach on alluvium. Subsoil is mottled and occasionally saline at depth. Poorly to imperfectly drained.	***Spencer* (Sp)** (Grey Sodosol, Brown Sodosol)
5	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim* (Bm)** (Black Vertosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
6	Plains and terrace plains on terraces and flood plains.	Deep to very deep, strongly acidic grey, brown and black cracking clays on alluvium. Subsoils are grey, mottled, strongly acidic, and/or occasionally sodic or saline. Buried horizons rarely encountered within 1.8 m. Poorly to imperfectly drained.	***Waterford* (Wa)** (Grey Vertosol, Brown Vertosol, Black Vertosol)
	Drainage impaired plains, swamps and drainage depressions of floodplains and terraces.	Deep to very deep grey cracking clay on alluvium. Subsoils are neutral to alkaline and may be sodic, calcic and/or saline at depth. Poorly to imperfectly drained.	***Basel* (Bs)** (Grey Vertosol, Aquic (Grey) Vertosol, Redoxic Hydrosol)
7	Plains and terrace plains on flood plains and terraces. Slope 0-2.5%.	Deep to very deep, brown and grey, acidic to neutral cracking clays. Light to medium heavy clays over brown and grey medium to heavy clays. Subsoils are acidic to neutral, mottled and often sodic.	***Payne* (Pn)** (Brown Vertosol, Grey Vertosol)
		Deep to very deep, brown, sporadically or conspicuously bleached, cracking (not self-mulching) clay soils on alluvium. Subsoils are acidic and frequently mottled. Poorly drained.	***Bridge* (Br)** (Brown Vertosol, Grey Vertosol)

Land use in this area includes grazing on lower quality soils such as *Waterford, Basel, Payne* and *Beausang* while *Blenheim* and *Bell (SEQ)* are mostly cultivated and cropped. Agricultural land classes range from A1 to C2. Limitations to agricultural suitability are presented in Table 30.

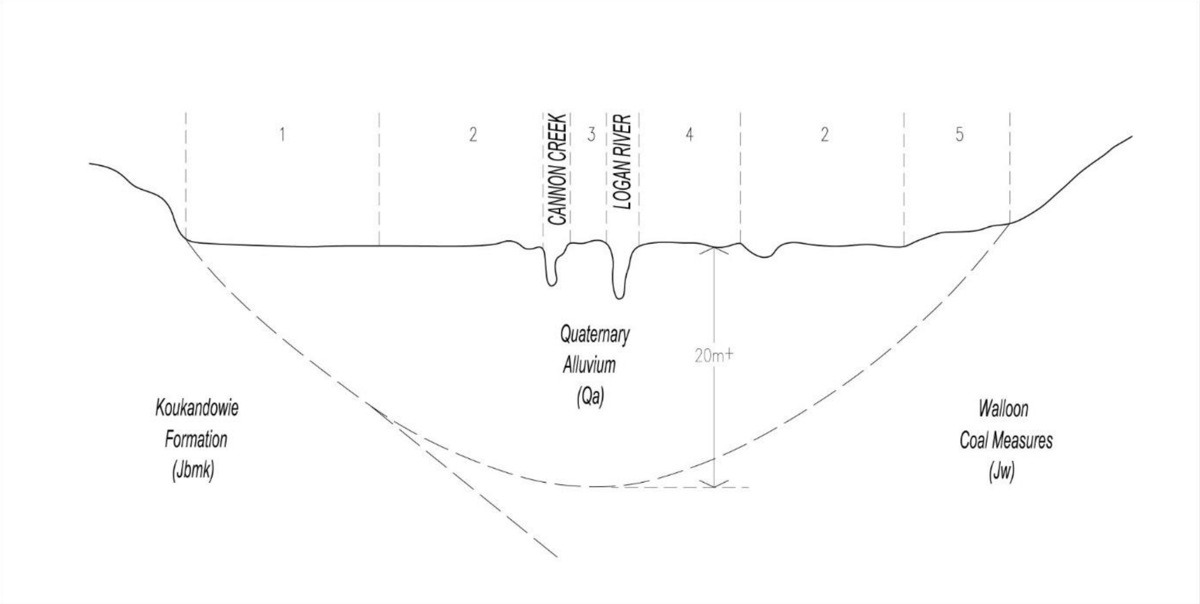
Table 30. Major limitations to agricultural suitability in Quaternary Alluvium landscape example 2

Soil Profile Class	Significant agricultural suitability limitations
Blenheim (Bm)	Frost, soil adhesiveness.
Beausang (Bg)	Wetness, soil water availability.
Bell (SEQ) (Bl)	Frost, flooding, landscape complexity.
Sippel (Sl)/Spencer (Sp)	Frost, soil water availability, nutrient deficiency, wetness.
Waterford (Wa)	Soil water availability, pH, wetness, frost.
Basel (Bs)	Wetness.
Payne (Pn)	Frost, pH wetness.
Bridge (Br)	Soil adhesiveness, frost, soil water availability, wetness.

9.14.3 Quaternary alluvium soil and landscape example 3: Logan River at Cannon Creek Junction

Deep, basalt dominated alluviums occur here in broad, flat alluvial plains. Basalt sediments are derived from upstream and surrounding hills and valleys while Cannon Creek, flowing through Gatton Sandstone and Koukandowie Formation, provides smaller volumes of sandier materials. These overlie pre-existing, eroded Koukandowie Formation and Walloon Coal Measures at depths often greater than 20 metres.

Soils range from deep black Chromosols (*Gunya*) with sandy loam to clay loam surfaces (often close to stream channels), to deep and very deep Dermosols (*Bremer* & *Bremer Buried Phase*) and very deep Black, self-mulching Vertosols (*Blenheim* & *Cooeeimbardi*).



Unit	Landform	Soil Description	Soil Profile Class
1	Plains, back plains, levees, fans and terrace plains on alluvial/flood plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, occasionally mottled, slightly saline and/or vertic. Buried horizons are not encountered within 1.8 m. Imperfectly to moderately well drained.	***Bremer* (B)** (Black or Brown or Grey Dermosol)
		As for Bremer with various buried alluvial horizons occurring within 1.8 m. Moderately well drained or imperfectly drained.	***Bremer Buried Phase* (BBp)** (Black or Brown or Grey Dermosol)
		Deep to very deep, alkaline, black texture-contrast soils on Quaternary alluvium. Loamy to clay loamy surfaces over black clays. Subsoils may be calcic and/or vertic. Moderately well drained to well drained.	***Gunyah* (Gy)** (Black Chromosol)
2	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
3	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
		Deep to very deep, alkaline, black texture-contrast soils on Quaternary alluvium. Loamy to clay loamy surfaces over black clays. Subsoils may be calcic and/or vertic. Moderately well drained to well drained.	***Gunyah* (Gy)** (Black Chromosol)
4	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim* (Bm)** (Black Vertosol)
		Deep to very deep, alkaline, black texture-contrast soils on Quaternary alluvium. Loamy to clay loamy surfaces over black clays. Subsoils may be calcic and/or vertic. Moderately well drained to well drained.	***Gunyah* (Gy)** (Black Chromosol)
5	Plains, terrace plains and back plains on alluvial/flood plains and terraces.	Deep to very deep self-mulching, neutral to alkaline, black cracking clay soils on alluvium. Subsoils are not calcic, rarely mottled and may be slightly saline. Moderately well drained, occasionally imperfectly drained.	***Cooeeimbardi* (Cb)** (Black Vertosol)

These, and similar landscapes, are the most agriculturally prized in the study area and are frequently irrigated. They support a wide range of high value cropping and grazing activities including dairy pasture, fodder, cropping (broad acre and horticultural) and turf. As would be expected, agricultural land class is generally A1. Table 31 lists the major limitations to agricultural suitability.

Figure 52. *Gunyah*, *Bremer* and *Cooeeimbardi* soil examples. Top row: *Gunyah* soil core and landscape on east side of Logan River down-stream of Cannon Creek (Site 610); Middle row: *Bremer* soil core and landscape (west bank of Cannon Creek) near Round Mountain (Site 2032); Bottom row: *Cooeeimbardi* soil core and alluvial plain landscape (Site 609).

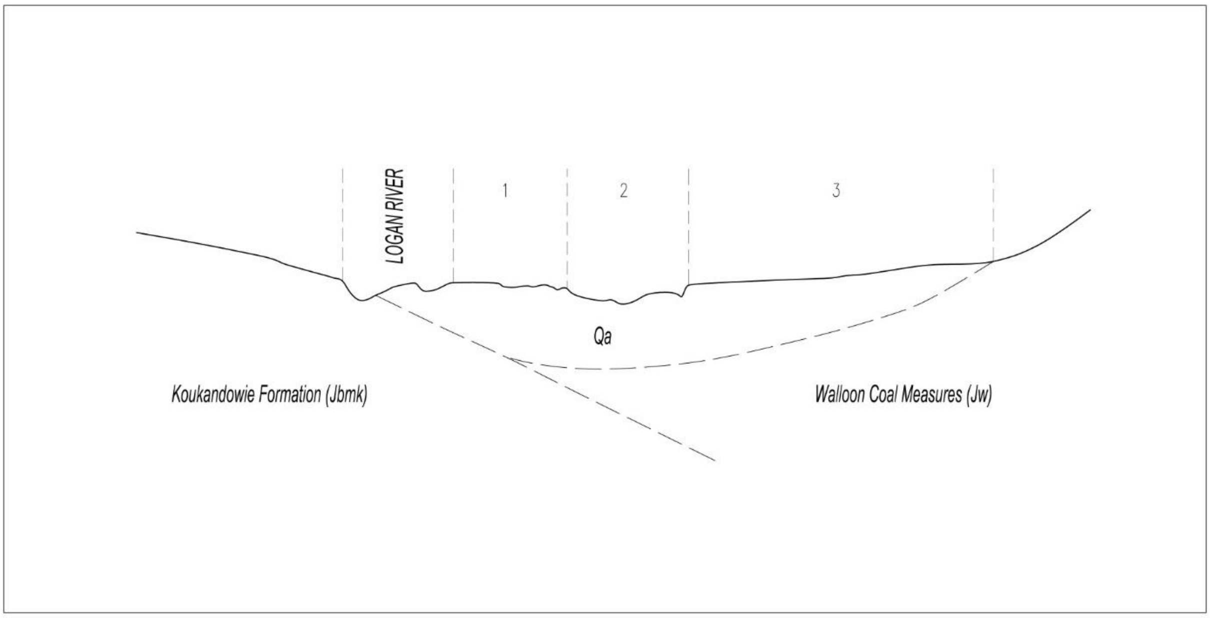
Table 31. Major limitations to agricultural suitability in Quaternary Alluvium landscapes 3

Soil Profile Class	Significant agricultural suitability limitations
Bremer (B)	Frost, flooding, soil water availability, wetness.
Bremer Buried Phase (BBp)	Frost, flooding, landscape complexity, wetness.
Gunyah (Gy)	Frost, flooding.
Bell (SEQ) (Bl)	Frost, flooding, landscape complexity.
Blenheim (Bm)	Frost, soil adhesiveness.
Cooeeimbardi (Cb)	Frost, flooding, landscape complexity.

9.14.3. Quaternary alluvium soil and landscape example 4: Logan River at Flanagan Reserve

Located in the Upper Logan River sub-catchment at Flanagan Reserve, these landscapes are surrounded by Koukandowie Formation hills to the west and Walloon Coal Measures low hills to the east. The Logan River flows through here approximately 16 km from its source in various sandstone, rhyolite and basalt geologies below Mount Lindesay.

The alluvium here is dominated by materials of sandstone and siltstone origin. This results in sandy, poorly structured Rudosols and Tenosols (*Jimboomba* & *Cressbrook*) close to the active stream channel grading to poorly drained, sodic Grey Chromosols and Sodosols (*Beausang*) further outward.



Unit	Landform	Soil Description	Soil Profile Class
1	Plains and terrace plains on flood plains and terraces.	Moderately deep to deep, brown, poorly structured, acidic to neutral, uniformly coarse soils formed on alluvium from a range of sources, often with buried horizons below. May be bleached.	***Jimboomba* (Jm)** (Orthic Tenosol)
2	Stream channels and stream banks on flood plains.	Very deep to giant, acid to neutral, coarse textured soils on alluvium over buried alluvial horizons and/or bedload. Rapidly to well drained.	***Cressbrook* (Cr)** (Stratic or Arenic Rudosol)
3	Terraces, plains, fans and valley flats of level to gently undulating plains and flood plains. Slope <5%.	Deep to very deep soils with a very strong texture contrast between A and B horizons formed on sandstone and siltstone influenced alluvium. Frequently bleached, grey and black sandy to clay loamy surfaces over mottled, slightly acidic to alkaline, often sandy, grey clays. Buried alluvial horizons are common. Very slowly to moderately permeable, poorly to imperfectly drained.	***Beausang* (Bg)** (Grey Chromosol, Grey Sodosol)

Land use is limited to grazing of native pastures with agricultural land classes of C1 or C2. Limitations to agricultural suitability are listed in Table 32.

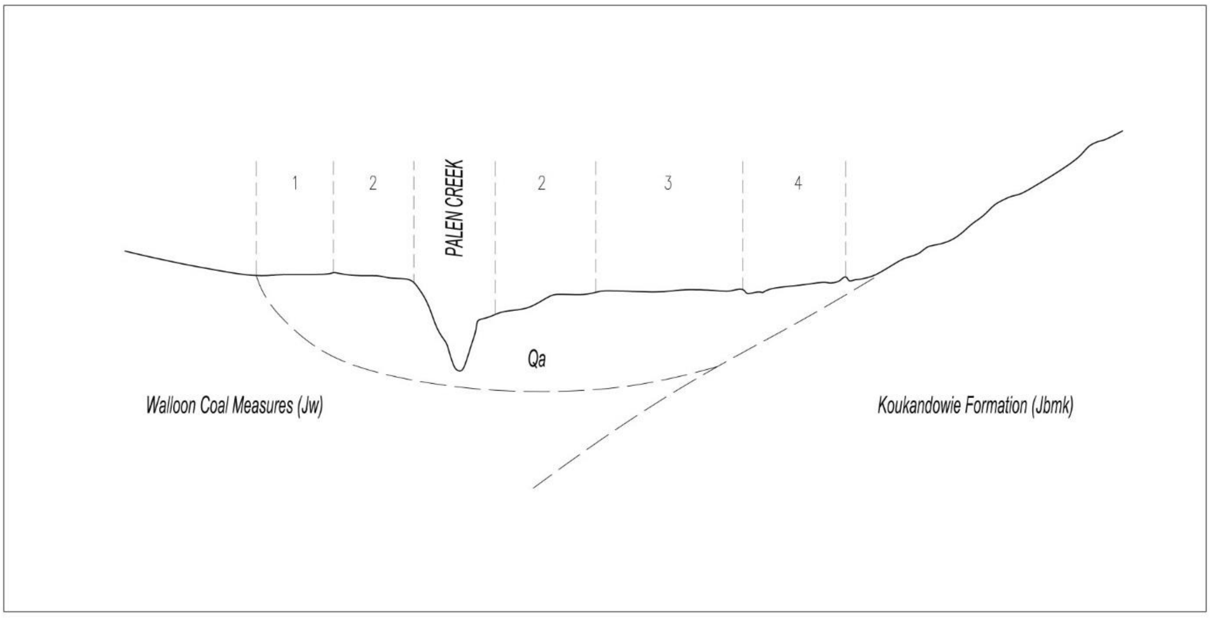
Table 32. Major limitations to agricultural suitability in Quaternary Alluvium landscapes 4

Soil Profile Class	Significant agricultural suitability limitations
Jimboomba (Jm)	Frost, flooding, soil water availability, nutrient deficiency, rockiness.
Cressbrook (Cr)	Frost, flooding, soil water availability, nutrient deficiency, rockiness, landscape complexity.
Beausang (Bg)	Frost, flooding, soil water availability, pH.

Figure 53. *Jimboomba* and *Beausang* soil examples. Top row: *Jimboomba* soil core and landscape beside the Logan River (on right) (Site 2010); Bottom row: *Beausang* soil core and alluvial plain landscape on west side of Logan River looking west to Mount Maroon (Site 324).

9.14.4. Quaternary alluvium soil and landscape example 5: Palen Creek at Back Creek

Mixed source alluvium (heavily basalt influenced) from Palen Creek and Back Creek has accumulated here at the junction of the two in a wider alluvial plain and terrace landscape producing a range of Black, Brown and Grey Dermosols (*Bremer*, *Lockyer*, *Monsildale* & *Lockrose*) and cracking to self-mulching Black Vertosols (*Cooeeimbardi, Blenheim* & *Bell (SEQ)*).



Unit	Landform	Soil Description	Soil Profile Class
1	Plains, terrace plains, levees and valley flats on flood plains, alluvial plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, slightly to mildly saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well or imperfectly drained.	***Bremer Buried Phase* (BBp)** (Black Dermosol, Brown Dermosol, Grey Dermosol)
2	Plains, terrace plains, levees and backplains on alluvial/flood plains and terraces.	Deep to very deep, black or brown, non-cracking gradational soils on mixed source alluvium. Clay loam surfaces over neutral to alkaline (often silty or sandy) clays. Occasionally faintly mottled, sodic or saline subsoils overly buried alluvial horizons. Moderately well drained.	***Lockyer* (Ly)** (Black or Brown Dermosol, Black or Brown Kandosol)
		Deep to very deep self-mulching, neutral to alkaline, black cracking clay soils on alluvium. Subsoils are not calcic, rarely mottled and may be slightly saline. Moderately well drained, occasionally imperfectly drained.	***Cooeeimbardi* (Cb)** (Black Vertosol)
3	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim* (Bm)** (Black Vertosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
4	Plains, terrace plains and terrace flats on flood plains and terraces.	Deep to very deep, neutral black or brown gradational soils on alluvium. Black clay loams over black and brown clays. Subsoils are neutral, weakly to moderately structured clays over buried horizons. Moderately well drained.	***Monsildale* (Mn)** (Black Dermosol, Brown Dermosol)
		Deep to very deep, black or grey (also brown) uniformly fine, non-cracking clay soil. Light clay to light medium clay over medium to medium heavy clay. Subsoils are neutral to alkaline and occasionally mottled, slightly saline or calcareous.	***Lockrose* (Ls)** (Black Dermosol, Grey Dermosol, Brown Dermosol)

Cultivation is common here with land uses including diary pasture and fodder crop production. Agricultural land class is A1 or A2. Limitations to agricultural suitability are listed in Table 33.

Table 33. Major limitations to agricultural suitability in Quaternary Alluvium landscapes 5

Soil Profile Class	Significant agricultural suitability limitations
Bremer Buried Phase (BBp)	Frost, flooding, landscape complexity, wetness.
Lockyer (Ly)	Frost, flooding, soil water availability.
Cooeeimbardi (Cb)	Frost, flooding, landscape complexity.
Blenheim (Bm)	Frost, soil adhesiveness.
Bell (SEQ) (Bl)	Frost, flooding.
Monsildale (Mn)	Frost, flooding.
Lockrose (Ls)	Frost, flooding.

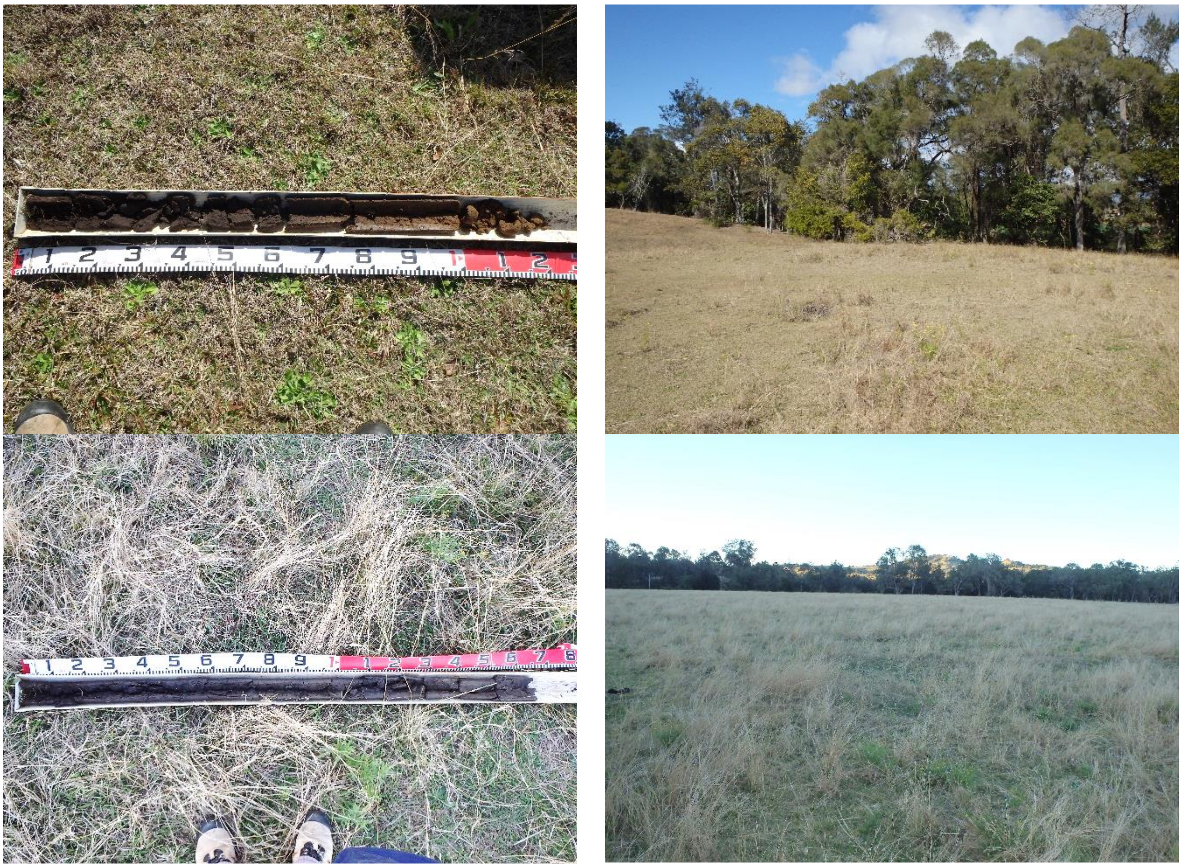
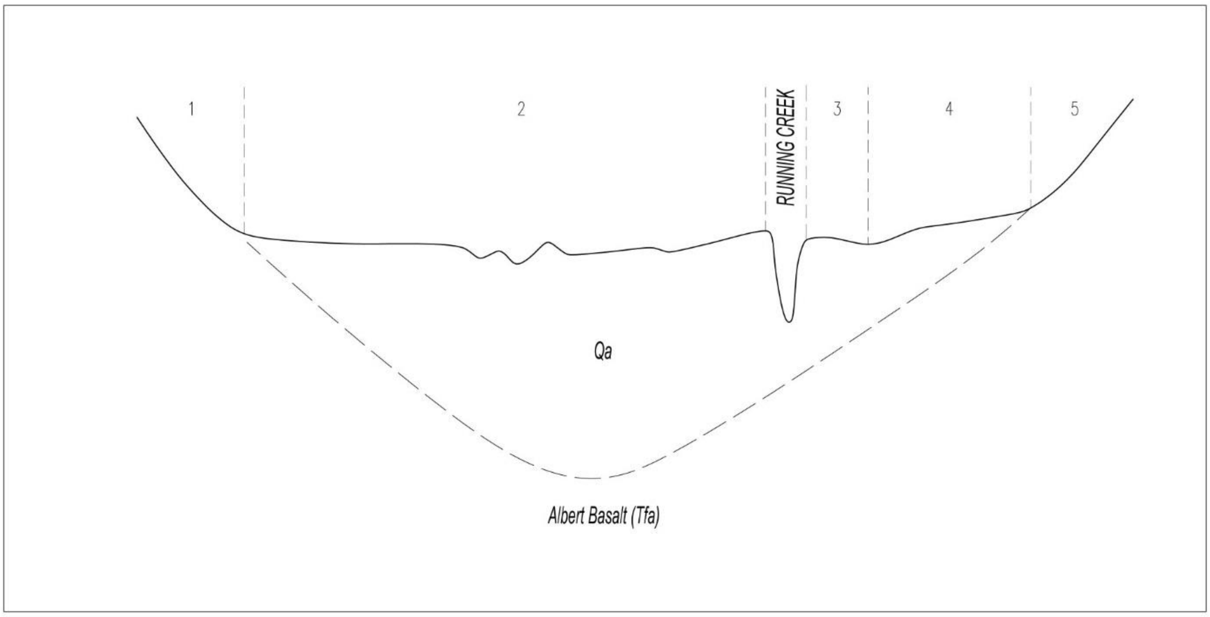


Figure 54. ***Monsildale*** **and** ***Bell (SEQ)*** **soil examples. Top row:** ***Monsildale*** **soil core and small alluvial flat landscape next to Back Creek (Site 2011); Bottom row:** ***Bell (SEQ)*** **soil core and alluvial plain landscape at junction of Back Creek and Logan River (Site 366).**

9.14.5. Quaternary alluvium soil and landscape example 6: Running Creek below New Year Creek

Running Creek valley is almost entirely Miocene basalt (largely Albert Basalt) with only a small proportion of Walloon Coal Measures, therefore, the alluviums in this area are all basalt derived. Gentle lower slopes on basalt with Black and Brown Vertosols (*Palen* and *Glenapp*) grade into very deep Black Vertosols (*Blenheim*, *Bell (SEQ)* & *Cooeeimbardi*) and occasional Dermosols (*Bremer Buried Phase*).



Unit	Landform	Soil Description	Soil Profile Class
1	Lower slopes, fans, foot slopes and benches of rolling to steep low hills and hills. Slopes <20%.	Deep to very deep, black, cracking clays on basalt and basalt colluvium. Subsoils are neutral to strongly alkaline, calcic, slightly gravelly and may have salinity at depth. Moderately well drained.	***Palen* (Pa)** (Black Vertosol, Brown Vertosol, Black Dermosol)
2	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim* (Bm)** (Black Vertosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or saline at depth. Poorly to moderately well drained.	***Bell (SEQ) (Bl)*** (Black Vertosol)
3	Plains, terrace plains, levees and valley flats on flood plains, alluvial plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well or imperfectly drained.	***Bremer Buried Phase* (BBp)** (Black Dermosol, Brown Dermosol, Grey Dermosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
4	Plains, terrace plains and backplains on alluvial/flood plains and terraces.	Deep to very deep self-mulching, neutral to alkaline, black cracking clay soils on alluvium. Subsoils are not calcic, rarely mottled and may be saline. Moderately well drained, occasionally imperfectly drained.	***Cooeeimbardi* (Cb)** (Black Vertosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)
5	Lower slopes, fans, foot slopes and benches of rolling to steep low hills and hills. Slopes <20%.	Deep to very deep, black, cracking clays on basalt and basalt colluvium. Subsoils are neutral to strongly alkaline, calcic, slightly gravelly and may have salinity at depth.	**Palen (Pa)** (Black Vertosol, Brown Vertosol)
		Very deep, neutral to alkaline, black, self-mulching, cracking clays and calcic subsoils on basalt and basalt colluvium. Moderately well drained.	**Glenapp (Gp)** (Black Vertosol)

The entire Running Creek valley floor and gentle lower slopes exhibit highly productive agricultural soils with current land uses that include broad acre cropping, fodder production and improved pastures. Agricultural land classification for these landscapes is either A1 or A2. Major limitations to agricultural suitability are listed in Table 34.

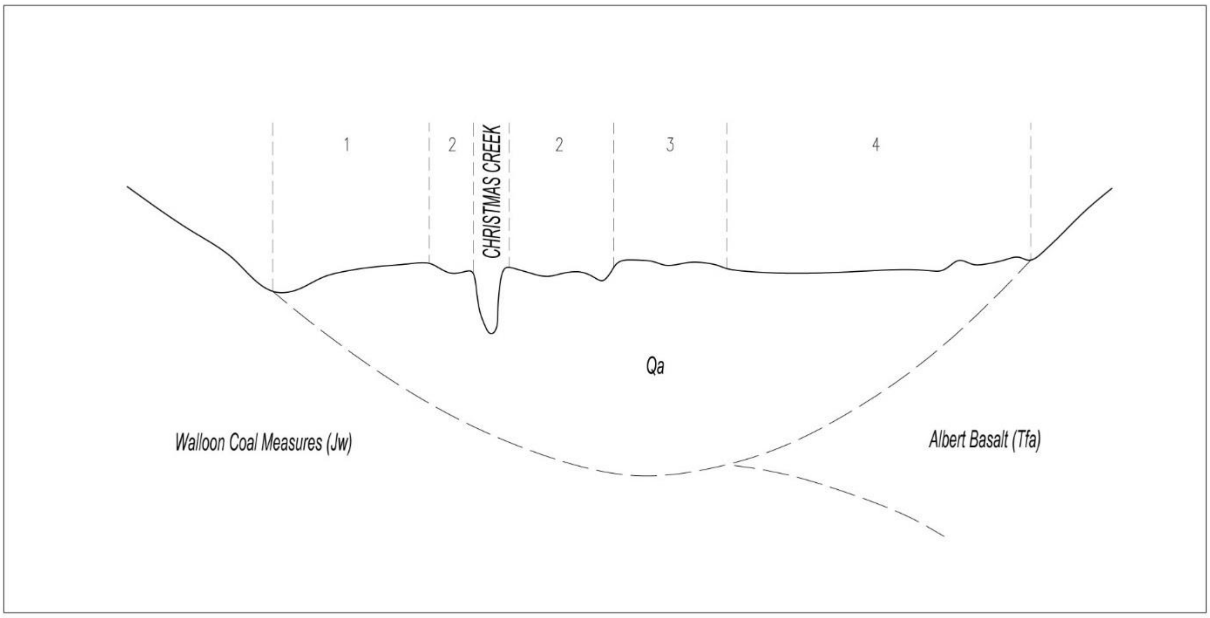
Table 34. Major limitations to agricultural suitability in Quaternary Alluvium landscapes 6

Soil Profile Class	Significant agricultural suitability limitations
Palen	None significant.
Blenheim (Bm)	Frost, soil adhesiveness.
Bell (SEQ) (Bl)	Frost, flooding.
Bremer Buried Phase (BBp)	Frost, flooding, landscape complexity, wetness.
Cooeeimbardi (Cb)	Frost, flooding, landscape complexity.
Glenapp (Gp)	None significant.

Figure 55. Palen and Bremer Buried Phase soil examples. Top row: Palen soil core and lower slope landscape (Site 450); Top row: Bremer Buried Phase soil core and gently undulating alluvial plain landscape (Site 455).

9.14.6. Quaternary alluvium soil and landscape example 7: Christmas Creek downstream of Widgee Creek

This landscape is similar to Running Creek in that its geology is almost wholly Miocene basalt, with the exception of a few small patches of exposed Walloon Coal Measures. Soils are also very similarly basalt dominated alluvium with Black Vertosols (*Blenheim* and *Bell (SEQ)*) surrounded by lower slopes and fans (*Palen, Chinghee* and *Lindesay*) and low hills and hills (*Chinghee, Tartar Shallow Phase, Sarabah* and *Gorman*). The presence of Dermosols (*Bremer Buried Phase*) and Black Chromosols (*Gunyah*) may be related to the underlying sandstone and Walloon Coal Measures.



Unit	Landform	Soil Description	Soil Profile Class
1	Plains, terrace plains, levees and valley flats on flood plains, alluvial plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, slightly to mildly saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well drained or imperfectly drained.	***Bremer Buried Phase* (BBp)** (Black or Brown or Grey Dermosol)
2	Plains and levees on flood plains and terraces.	Deep to very deep, alkaline, black texture-contrast soils on Quaternary alluvium. Loamy to clay loamy surfaces over black clays. Subsoils may be calcic and/or vertic. Moderately well drained to well drained.	***Gunyah* (Gy)** (Black Chromosol)
3	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim* (Bm)** (Black Vertosol)
4	Plains and terrace plains on alluvial/flood plains and terraces.	Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or slightly saline at depth. Poorly to moderately well drained.	***Bell (SEQ)* (Bl)** (Black Vertosol)

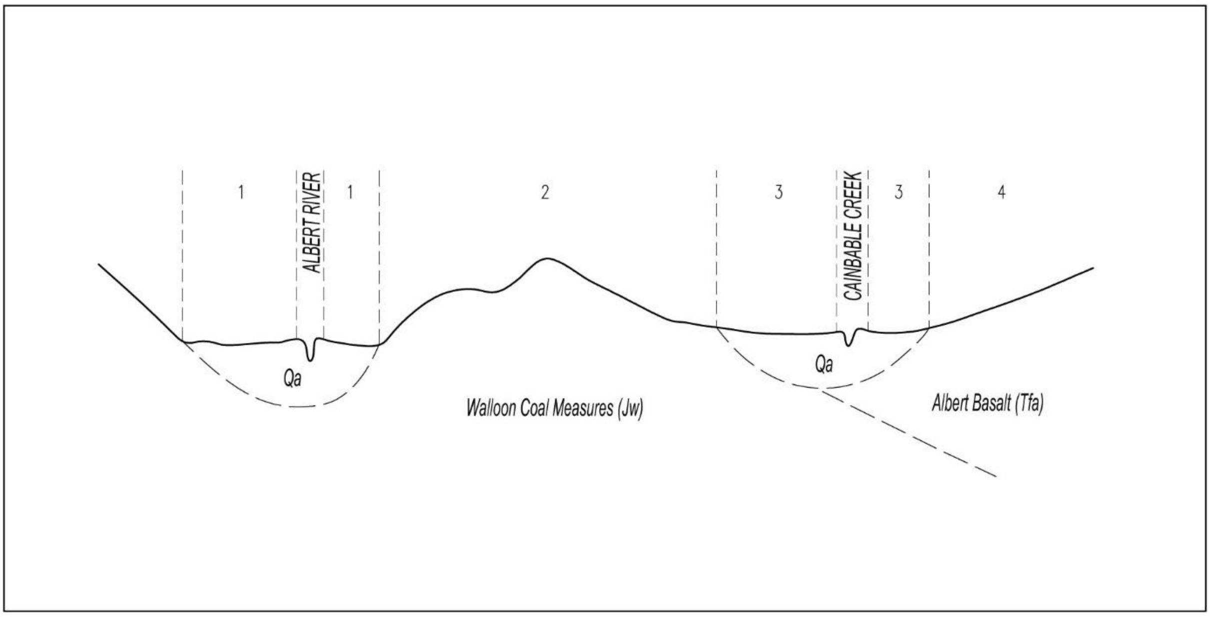
Land use is also similar to other basalt derived alluviums, with uses that include broad acre cropping, dairy, fodder production and improved pastures. Agricultural land classification for these landscapes is either A1 or A2. Major limitations to agricultural suitability are in Table 35.

Table 35. Major limitations to agricultural suitability in Quaternary Alluvium landscape 7

Soil Profile Class	Significant agricultural suitability limitations
Bremer Buried Phase (BBp)	Frost, flooding, landscape complexity, wetness.
Gunyah (Gy)	Frost, flooding.
Blenheim (Bm)	Frost, soil adhesiveness.
Bell (SEQ) (Bl)	Frost, flooding.

Figure 56. *Blenheim* and *Bell (SEQ)* soil examples. Top row: *Blenheim* soil core and alluvial plain landscape with low hills of Walloon Coal Measures in the foreground and Albert Basalt hills in the background (Site 643); Bottom row: *Bell (SEQ)* soil core and alluvial plain landscape with basalt fan in the foreground and Albert Basalt hills and mountains in the distance (Site 630).

9.14.7. Quaternary alluvium soil and landscape example 8: Albert River and Cainbable Creek at Nindooinbah (prior to merging)



Unit	Landform	Soil Description	Soil Profile Class
1	Plains, terrace plains, levees and valley flats on alluvial/flood plains and terraces.	Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim*** **(Bm)** (Black Vertosol)
		Deep to very deep black cracking (but not self-mulching) clays on alluvium. Subsoils are alkaline and may be calcic, mottled and/or saline at depth. Poorly to moderately well drained.	***Bell (SEQ)*** **(Bl)** (Black Vertosol)
2	Slopes (rarely crests or ridges) of undulating to rolling rises to hills. Slopes <25%.	Moderately deep, red or brown, neutral to strongly alkaline non-cracking gradational and uniformly fine soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over sandstone or siltstone from 0.5 m. Subsoil and/or saprolite often contains calcareous or manganiferous/ferromanganiferous nodules. Imperfectly to moderately well drained.	***Nindooinbah*** **(Ni)** (Red or Brown Dermosol)
		Deep to very deep, red or brown, neutral to strongly alkaline non-cracking uniformly fine (rarely gradational) soils with a dark surface horizon underlain by frequently mottled brown, yellow or grey subsoils over Walloon sandstone or siltstone from 1.0 m. Imperfectly to moderately well drained.	***Nindooinbah Deep Phase*** **(NiDp)** (Red or Brown Dermosol)
3	Plains, terrace plains, levees and valley flats on flood plains, alluvial plains and terraces.	Deep to giant, uniformly fine textured, non-cracking, black, brown and grey soils. Subsoils are neutral to alkaline, non-calcic, non-sodic, occasionally mottled, saline and/or vertic. Various buried alluvial horizons occur within 1.8 m. Moderately well or imperfectly drained.	***Bremer Buried Phase*** **(BBp)** (Black or Brown or Grey Dermosol)
		Deep to very deep, black, cracking, self-mulching clays on alluvium. Subsoils are alkaline and calcic. May be saline at depth and may overlie buried alluvial horizons. Imperfectly to moderately well drained.	***Blenheim*** **(Bm)** (Black Vertosol)
4	Lower slopes, benches, fans and foot slopes of rolling and steep low hills, hills and mountains. Slope 1-15% (rarely 20%).	Deep to very deep black and brown, uniformly fine, non-cracking soils over basalt from 1.0m. Subsoils are neutral to alkaline and may be slightly gravelly, vertic and/or calcic. Salinity is rare. Moderately well drained.	***Tartar*** **(Tt)** (Black or Brown Dermosol)
		Deep to very deep, black, cracking clays on basalt and basalt colluvium. Subsoils are neutral to strongly alkaline, calcic, slightly gravelly and may have salinity at depth. Moderately well drained.	***Palen*** **(Pa)** (Black or Brown Vertosol, Black Dermosol)

Once again the alluviums here are predominately derived from basalt materials upstream, however, they are also influenced by surrounding low hills of Walloon Coal Measures to the west and between the Albert River and Cainbable Creek. Wide alluvial plains either side of both waterways are home to deep or very deep Black Vertosols (*Blenheim* & *Bell (SEQ)*) and Brown Dermosols (*Bremer Buried Phase*) grading to deep Black and Brown Dermosols (*Tartar*) and Vertosols (*Palen*) on lower slopes and fans to the west. Red and Brown Dermosols (*Nindooinbah* & *Nindooinbah Deep Phase*) occupy the low hills in between streams and transition to shallow Black and Brown Dermosols (*Sarabah*) and Vertosols (*Gorman*) on basalt hills further south.

Figure 57. *Nindooinbah Deep Phase* and *Blenheim* soil examples. Top row: *Nindooinbah Deep Phase* soil core and lower slope pasture landscape (Site 2126); Middle row: *Blenheim* soil core and cultivated (soya beans) alluvial landscape looking south toward Site 2126 (Site2125); Bottom row: *Blenheim* soil core and alluvial pasture landscape looking east to Cainbable Creek with Walloon Coal Measures low hills and Albert Basalt hills in the distance (Site 2091).

The alluvial plains and footslopes/fans are actively cultivated for a range of broad acre and fodder crops including corn, soya beans and lucerne. The central low hills are used for cattle grazing on generally unimproved pastures, however, some development of intensive animal production (poultry) is evident. Agricultural land class is A1 on alluvial plains, A1 or A2 on foot slopes/fans and C1 to C2 on sandstone/siltstone low hills. Limitations to agricultural suitability are listed in Table 36.

Table 36. Major limitations to agricultural suitability in Quaternary Alluvium landscapes 8

Soil Profile Class	Significant agricultural suitability limitations
Blenheim (Bm)	Frost, soil adhesiveness.
Bell (SEQ) (Bl)	Frost, flooding.
Nindooinbah (Ni)	Erosion, soil water availability, soil depth, landscape complexity, wetness.
Nindooinbah Deep Phase (NiDp)	Erosion, soil water availability, slope.
Bremer Buried Phase (BBp)	Frost, flooding, landscape complexity, wetness.
Palen (Pa)	None significant.
Tartar (Tt)	Erosion, salinity.

10. Soil chemical and physical properties

The following section summarises the available soil chemical and physical information for a range of soils within the project area. It is divided into subsections based, as in above chapters, on underlying geology. Where laboratory analysed data is incomplete or not available, field measured soil properties are reported.

A total of 30 sites were sampled for laboratory analysis, representing 15 SPC's describing the soils most commonly used for agricultural production (predominately alluvial and colluvial soils) and their locations were chosen to cover the largest and most productive current farming areas. These 30 sites include 19 analysed for this current study (Table 37) and 11 that were analysed as part of previous studies that overlap this one (Table 38).

Due to project constraints, six of the recently sampled 19 LARA sites have chemistry from only a limited number of horizons and no bulk surface sample (these are marked with a (P) in Table 37). All samples were analysed for exchangeable cations, cation exchange capacity (CEC), pH, electrical conductivity (EC), chloride, particle size (percentages of clay, silt and sand) and soil water content. From these Exchangeable Sodium Percentage (ESP), Calcium to Magnesium ratio (Ca:Mg) and clay activity ratio (CEC/clay%) are calculated. Site morphology and chemical analysis results for these 30 sites are presented in Appendix 3.

Table 37. Laboratory analysed sites within the LARA study area

SPC represented	Project	Site No.	SPC represented	Project	Site No.
Soils on Quaternary Alluvium			**Soils on Neogene to Pleistocene colluvium**		
Basel (Bs)	LARA	9014 (P)	*Glenapp* (Gp)	LARA	9008 (P)
Basel (Bs)	SEQ	402	*Glenapp* (Gp)	LARA	9016 (P)
Bell (SEQ) (Bl)	LARA	9001	*Wonglepong* (Wo)	LARA	9010 (P)
Bell (SEQ) (Bl)	LARA	9006 (P)			
Bell (SEQ) (Bl)	SEQ	95	**Soils on Neogene basalts**		
Bell (SEQ) (Bl)	SEQ	115	*Glenapp* (Gp)	LARA	9004 (P)
Bell (SEQ) (Bl)	SEQ	383	*Glenapp* (Gp)	LARA	9007
Bell (SEQ) (Bl)	SEQ	393	*Tamborine* (Ta)	SOC	11
Blenheim (Bm)	LARA	9002			
Blenheim (Bm)	LARA	9009	**Soils on Beaudesert Beds**		
Blenheim (Bm)	LARA	9012	*Saville* (Sv)	LARA	9017 (P)
Blenheim (Bm)	LARA	9013 (P)			
Blenheim (Bm)	LARA	9015 (P)	**Soils on Walloon Coal Measures**		
Blenheim (Bm)	LARA	9018 (P)	*Gould* (Gd)	MFM	425
Bremer Buried Phase (BBp)	LARA	9003 (P)			
Gunyah (Gy)	LARA	9005	**Soils on Koukandowie Formation**		
Hooper (Hr)	LARA	9011 (P)	*Koukandowie* (Kk)	SEQ	152
Kilmoylar (Km)	LARA	9000 (P)			
Kilmoylar (Km)	SEQ	162			
Sippel (Sl)	SPFD	108			
Waterford (Wa)	SEQ	317			

A number of SPC's in this report are found in previous land resource studies covering areas around Boonah, Teviot Brook, Albert River, Brisbane Valley and the Lockyer Valley. While these SPC's lie outside the boundary of this project they have common attributes and chemistry to those in the study area. Table 38 lists these sites and their SPC's, all of which are soils formed on Quaternary

(Pleistocene to Holocene) alluvium. For further detail consult the relevant land resource reports or alternatively the data can be viewed on the Queensland Government Globe.

Table 38. Laboratory analysed sites outside the LARA study area with common SPC's

Project*	Site Numbers	SPC represented	Project*	Site Numbers	SPC represented
BNH	215, 259, 263, 316, 538, 541, 609	*Bremer* (B)	LOC	783, A19, A20, C46, BL-D, BL-M, BL-S	*Blenheim* (Bm)
BNH	36, 256, 359, 532, 793	*Lockrose* (Ls)	LOC	Z3	*Lockyer* (Ly)
BNH	353, 403, 638	*Lockyer* (Ly)	LOC	E12	*Robinson* (Rs)
BNH	647	*Maroon* (Mr)	LOC	A26, Z6, Z19	*Sippel* (Sl)
BVL	2472, S12	*Basel* (Bs)	SEQE	17[#]	*Cressbrook* (Cb)
BVL	910, S17	*Cooeeimbardi* (Cb)	SEQE	21	*Monsildale* (Mn)
BVL	1392	*Cressbrook* (Cr)	SEQE	131	*Spencer* (Sp)
BVL	S13	*Duggua* (Du)	TVB	S1, S4	*Bell (SEQ)* (Bl)
BVL	S20	*Gunyah* (Gy)			
BVL	832	*Monsildale* (Mn)			
BVL	S11, S15	*Spencer* (Sp)			

*****BNH (Loi *et al*. 2005); LOC (Powell *et al*. 2002); TVB (Christianos *et al*. 1986); BVL (Harms & Pointon 1999); SEQE (Dear *et al*. 2017). Underlined sites include surface fertility results.
[#]SEQE 17 contains surface fertility results only.

10.1 Soil analysis methods

Where possible/required, profiles were sampled to a depth of 1.5 m and analysed at standard intervals. Analysed depths were occasionally altered to allow for thin surface horizons or where standard depths would cross soil horizon boundaries (Baker & Eldershaw 1993).

Appendix 3 of this report contains the reported analysis results and the laboratory methods used. Further information on analytical interpretation and laboratory methods can be found in Baker and Eldershaw (1993) and Rayment and Lyons (2011).

Results for surface fertility were available for 16 of the sampled profiles within the study area, covering 10 SPC's on Pleistocene to Holocene alluvial plains, the Neogene basalts and Triassic to Jurassic sediments.

Field recorded soil chemical and physical properties include measurements of pH (Raupach & Tucker 1959), salinity (1:5 electrical conductivity), sodicity (estimated by field dispersion testing and abbreviated to Disp. in tables following) and estimated soil moisture holding capacity (plant available water capacity-PAWC-estimated using field textures) (Department of Natural Resources and Mines and Department of Science Information Technology, Innovation and the Arts 2013). The "Likely Fertility" column refers to the fertility of the soil horizons likely to be used for agricultural purposes (commonly the A horizon) and is an inferred measure combining indicators such as pH, soil texture, soil colour and salinity.

Soil pH categories used to describe field recorded soil properties are as defined by Baker and Eldershaw (1993). The pH, EC and PAWC categories used (and their codes) are listed in Table 39.

Table 39. Field measured soil properties - pH, conductivity (EC) and PAWC codes used

pH code	pH code meaning	pH value	EC code	EC code meaning	EC value (dS/m)	PAWC code	PAWC code meaning	PAWC value (mm/m)
E-Acid	Extremely acidic	<4.5	VL	Very low	<0.1	VL	Very low	<20
VS-Acid	Very strongly acidic	4.5-5.0	L	Low	0.1-<0.25	L	Low	20-<50
S-Acid	Strongly acidic	5.1-5.5	M	Moderate	0.25-<0.5	M	Moderate	50-<90
M-Acid	Medium acidic	5.6-6.0	H	High	0.5-<1.0	H	High	90-<110
SL-Acid	Slightly acidic	6.1-6.5	VH	Very high	1.0-<1.5	VH	Very high	>110
N	Neutral	6.6-7.3	EH	Extremely high	>1.5			
M-Alk	Mildly alkaline	7.4-7.8						
MO-Alk	Moderately alkaline	7.9-8.4						
S-Alk	Strongly Alkaline	8.5-9.0						
VS-Alk	Very strongly alkaline	>9.0						

10.1. Soils developed on the Neranleigh-Fernvale Beds

Soils formed on the Neranleigh-Fernvale Beds are *Corbould, Ferny* and *Neranleigh.* Knowledge of the chemistry of these soils (Table 40) is very limited, however, from the field measured information available they can be characterised as strongly acidic soils of poor to low fertility that are not saline or sodic. As these are largely clay soils their capacity to store moisture is considered high. However, their low pH will influence the balance of nutrients available with clay surfaces likely to be dominated by less desirable ions such as aluminium, manganese and iron while key plant growth elements such as nitrogen, phosphorus and potassium will be less available or leached from the profile.

Table 40. Field-measured properties of soils developed on the Neranleigh-Fernvale Beds

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Corbould (Cd)	S-Acid to E-Acid	VS-Acid to E-Acid	VL	M	No	L	Poor
Ferny (Fy)	M-Acid to VS-Acid	M-Acid to VS-Acid	L	M	No	VL	Poor
Neranleigh (Nr)	S-Acid to N	E-Acid to N	L	L	No	M	Low

10.2. Soils developed on the Mount Barney Beds sediments

Soils formed on the Mount Barney Beds are *Clutha* and *Ferny.* Knowledge of the chemistry of these soils (Table 41) is very limited, however, from the field measured information available they can be characterised as moderately acidic soils of poor fertility. They are not significantly saline, but *Clutha* may be sodic. *Clutha* has a moderate ability to store moisture, but as these are largely sandy soils their capacity to store moisture and nutrients is considered low. (Cation-exchange capacity (CEC) is likely to be low).

Table 41. Field-measured properties of soils developed on the Mount Barney Beds

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Clutha (Cl)	M-Acid	M-Acid	VL	L	Possible	M	Poor
Ferny (Fy)	M-Acid	M-Acid	L	L	No	VL	Poor

10.3. Soils developed on the Chillingham Volcanics

Soils formed on the Chillingham Volcanics are *Ernest* and *Philp.* Knowledge of the chemistry of these soils (Table 42) is very limited, however, from the field measured information available they can be characterised as strongly acidic soils of low to moderate fertility that are not saline or sodic. As these are primarily clay soils their capacity to store moisture is considered high. However, their low pH will influence the balance of nutrients available with clay surfaces likely to be dominated by less desirable ions such as aluminium, manganese and iron while key plant growth elements such as nitrogen, phosphorus and potassium will be less available.

Table 42. Field-measured properties of soils developed on the Chillingham Volcanics

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Ernest (Er)	VS-Acid to S-Acid	S-Acid	VL	VL	No	H	Low to moderate
Philp (Pp)	VS-Acid to S-Acid	S-Acid	VL	VL	No	H	Low to moderate

10.4. Soils developed on the Ipswich Coal Measures

Soils formed on the Ipswich Coal Measures are *Clutha, Kooralbyn* and *Yarrabilba.* Knowledge of the chemistry of these soils (Table 43) is very limited, however, from the field measured information available they can be characterised as very strongly acidic soils of poor fertility with very low salinity and sodicity levels. As these soils have sandy textures (texture contrast and uniformly coarse) their capacity to store moisture and nutrients (probable low CEC) is considered low. Their low pH will influence the balance of nutrients available with clay surfaces likely to be dominated by less desirable ions such as aluminium, manganese and iron while key plant growth elements such as nitrogen, phosphorus and potassium will be less available.

Table 43. Field-measured properties of soils developed on the Ipswich Coal Measures

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Clutha (Cl)	VS-Acid to S-Acid	VS-Acid to S-Acid	VL	L	Possible	M	Poor
Kooralbyn (Ko)	VS-Acid to S-Acid	VS-Acid to S-Acid	VL	VL	Possible	M	Poor
Yarrabilba (Ya)	VS-Acid to S-Acid	VS-Acid to S-Acid	VL	L	No	L	Very poor

10.5. Soils developed on Triassic to Jurassic sediments

This section discusses the chemical and physical properties of soils formed on the Woogaroo Subgroup, Gatton Sandstones, Koukandowie Formation and the Walloon Coal Measures.

10.5.1 Soils formed on the Woogaroo Subgroup sediments

Soils formed on the Woogaroo Subgroup are *Clutha, Kooralbyn, Kooralbyn Deep Phase, Lowood, Koukandowie* and *Yarrabilba.* The available field measured properties in Table 44 indicate these soils can be characterised as moderately to very strongly acidic soils of very poor to low fertility. *Clutha, Kooralbyn Deep Phase* and *Lowood* soils exhibit moderate subsoil salinity while *Lowood* and

Koukandowie soils have sodic B horizons. As these are largely sandy texture contrast and uniformly coarse soils their capacity to store moisture and nutrients (low A horizon CEC is likely) is considered low. Their low pH will influence the balance of nutrients available, clay surfaces likely to be dominated by less desirable ions such as aluminium, manganese and iron while key plant growth elements such as nitrogen, phosphorus and potassium will be less available.

Table 44. Field-measured properties of soils developed on the Woogaroo Subgroup

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Clutha (Cl)	VS-Acid to M-Acid	S-Acid to N	L	M	No	M	Poor
Kooralbyn (Ko)	S-Acid to N	VS-Acid to M-Acid	VL	VL	No	M	Low
Kooralbyn Deep Phase (KoDp)	S-Acid to M-Acid	VS-Acid to S-Acid	VL	M	No	M	Low
Lowood (Lw)	S-Acid to M-Acid	S-Acid to S-Alk	VL	L-M	Yes	L	Low
Koukandowie (Kk)	S-Acid to M-Acid	M-Acid to N	VL	L	Yes	L	Low
Yarrabilba (Ya)	VS-Acid to S-Acid	VS-Acid to S-Acid	VL	L	No	L	Very poor

10.5.2 Soils formed on Gatton Sandstone

Soils formed on Gatton Sandstone are *Birnam, Cedar Vale, Dulbolla, Dulbolla Sodic Phase, Flanagan, Glenoake, Gould, Hardgrave, Kagaru, Knapp, Knapp Acidic Phase, Koukandowie, Lowood, Mundoolun, Pine Vale, Rathdowney, Stockleigh, Flanagan* and *Woollaman* (Table 45).

Birnam, Dulbolla Sodic Phase, Flanagan, Gould, Knap Acidic Phase and *Pine Vale* are all strongly or very strongly acidic soils and will have colloidal surfaces likely be dominated by less desirable ions such as aluminium, manganese and iron while key plant growth elements such as nitrogen, phosphorus and potassium will be less available. The remaining range from slightly acidic to neutral or mildly alkaline and will probably have a wider range and higher availability of nutrients.

Surface salinity for all Gatton Sandstone soils is very low to low, while subsoil conductivity increases to moderate in *Dulbolla, Dulbolla Sodic Phase, Kagaru, Koukandowie, Pine Vale* and *Stockleigh.*

Sodicity is consistently strong in *Dulbolla Sodic Phase, Koukandowie* and *Lowood* soils while others such as *Rathdowney* are occasionally sodic.

Available moisture (PAWC) varies from very low to low in sodic (root access to subsoil moisture is restricted by sodicity) and very sandy soils (*Woollaman*) to very high in deep, clay dominated and non-sodic *Dulbolla* and *Kagaru* soils. Remaining soils have a moderate ability to retain available moisture.

Fertility, as estimated by the Likely Fertility, is generally poor to low and affected by low soil pH and low clay content, both of which are evident in *Woollaman* soils. Many of the texture contrast (duplex) soils also fall into the lower fertility categories due largely to their sandy A horizons with probable low or very low CEC values. In contrast the higher clay percentage and higher pH soils such as *Richards* and *Kagaru* are likely to have high fertility. The remainder of the soils are likely to be of moderate fertility.

Table 45. Field-measured properties of soils developed on the Gatton Sandstones

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Birnam (Bi)	VS-Acid to SL-Acid	S-Acid to SL-Acid	L	H	No	M	Mod
Cedar Vale (Cv)	M-Acid	M-Acid	L	L	No	L	Low
Dulbolla (Db)	SL-Acid to N	SL-Acid to M-Alk	L	M	No	VH	Mod
Dulbolla Sodic Phase (DbSp)	M-Acid	VS-Acid	L	M	Yes	L	Low
Flanagan (Fl)	S-Acid to M-Acid	VS-Acid	VL-L	L	No	M	Mod
Glenoake (Gl)	VS-Acid to M-Acid	SL-Acid to S-Alk	L	L	No	M	Mod
Gould (Gd)	S-Acid to SL-Acid	VS-Acid to SL-Acid	L	L	No	H	Mod
Hardgrave (Ha)	SL-Acid	SL-Acid to M-Alk	VL	L	No	H	Mod
Kagaru (Ka)	SL-Acid to M-Alk	N to S-Alk	L	M	No	VH	High
Knapp (Kn)	SL-Acid to M-Alk	SL-Acid to N	L	L	No	M	Mod
Knapp Acidic Phase (KnAp)	SL-Acid	VS-Acid	VL	VL	No	M	Low
Koukandowie (Kk)	M-Acid to SL-Acid	S-Acid to S-Alk	VL-L	L-M	Yes	L	Low
Lowood (Lw)	M-Acid to SL-Acid	M-Acid to MO-Alk	VL	L	Yes	L	Low
Mundoolun (Mu)	S-Acid to M-Acid	M-Acid to N	L	L	No	M	Low
Pine Vale (Pv)	S-Acid to M-Acid	VS-Acid to N	VL-L	L-M	No	L-M	Low
Rathdowney (Ra)	M-Acid to N	M-Acid	VL	VL-L	Rare	M-H	Low
Stockleigh (St)	M-Acid	M-Acid to MO-Alk	L	M	No	M	Low
Woollaman (Wm)	VS-Acid to M-Acid	VS-Acid to M-Acid	L	L	No	VL	Poor

10.5.3 Soils formed on Koukandowie Formation sediments

The only SPC sampled for laboratory analysis on the Koukandowie Formation sediments was *Koukandowie*. Selected chemical properties of this soil are presented in Table 46 and Figures 58 and 59. This brown, texture contrast *Koukandowie* soil has a moderately to strongly acidic soil reaction trend with salinity that steadily increases from a moderate level at the surface to high below 0.5 m. These pH and EC/chloride levels are only likely to restrict the root exploration of sensitive plants.

Exchangeable sodium percentage (ESP) increases consistently down the profile, reaching strongly sodic levels (ESP 18 to 38%; dispersion ratio 0.79 to 0.99) from 0.2-0.3 m (Figure 58). From 0.5-0.6 m downwards the amount of exchangeable sodium exceeds that of Calcium by a factor of at least 2. Restricted drainage and permeability can be expected (and were recorded in the field) from high sodicity and these high concentrations of sodium alone (regardless of ESP) may also be toxic to some plant species e.g. citrus and avocado. CEC increases down the profile (Figure 58) from moderate (surface) to high (subsoil), however, clay activity ratio remains relatively constant at 0.5-0.6 indicating the likely presence of illite based, non-expanding clays.

Table 46. Selected properties of a laboratory analysed *Koukandowie* soil formed on Koukandowie Formation sediments

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. ratio	CEC/ clay%	Ca:Mg ratio
Koukandowie **(SEQ Site 152)**									
0-0.1	5.5	0.18	80	12	5.8	3.8	0.35	0.5	1.6
0.2-0.3	6.0	0.34	357	37	17	18	0.79	0.5	0.4
0.5-0.6	5.4	0.59	734	36	18	33	0.98	0.5	0.3
0.8-0.9	5.1	0.38	1190	41	24	38	0.99	0.6	0.3
1.1-1.2	5.1	0.79	309	37	23	37	-	0.6	0.3

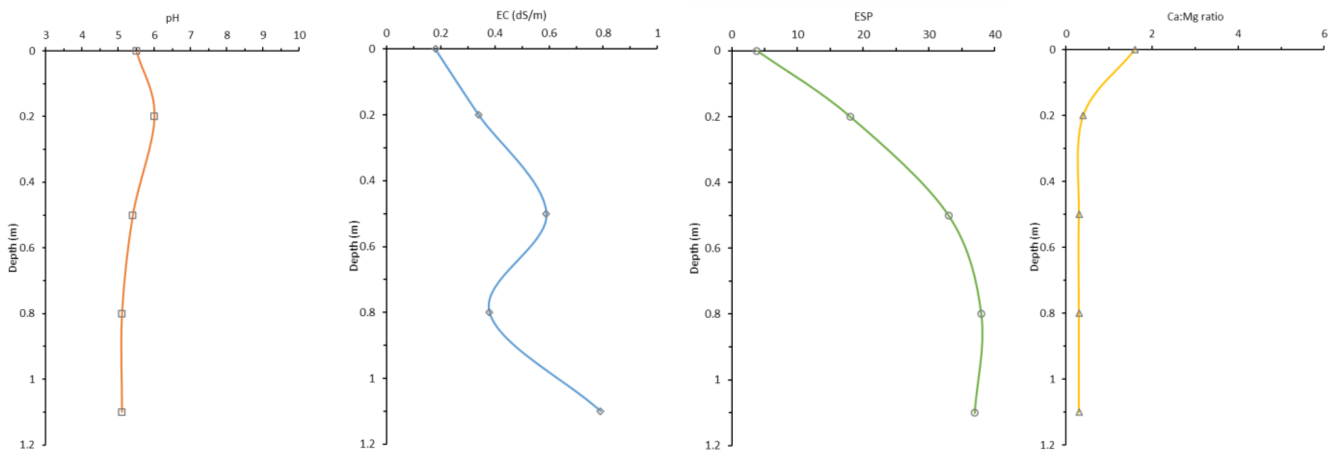


Figure 58. Profile pH, EC, ESP and Ca:Mg ratio for a *Koukandowie* soil developed on Koukandowie Formation sediments

Ca:Mg ratios suggest that magnesium again dominates the exchange complex, closely followed by sodium then calcium. Imbalances such as these will exacerbate sodicity effects and reduce CEC available to more favourable cations (below 0.5 m exchangeable potassium at this site falls below 2%). Additionally, due to the strongly acid subsoil, exchangeable aluminium concentrations of 0.5 to 2% were reported in subsoils. Clay content of this *Koukandowie* soil (Figure 59) is as expected, with surface levels of 12% increasing sharply to 37 to 41% in subsoils.

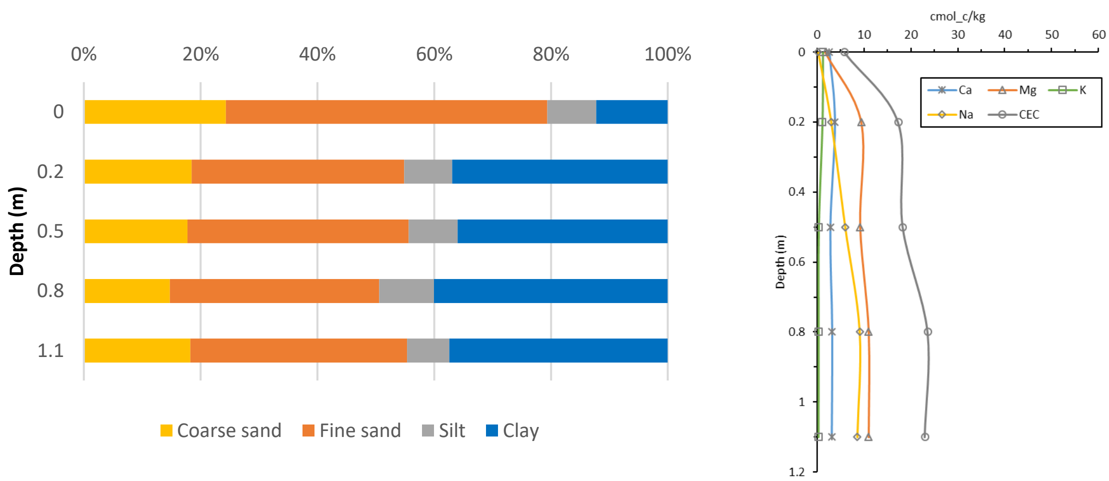


Figure 59. Particle size analysis (left), CEC and cations (right) for a *Koukandowie* soil

Other soils formed on the Koukandowie Formation sediments are *Birnam, Cedar Vale, Dulbolla, Dulbolla Sodic Phase, Flanagan, Glenoake, Gould, Hardgrave, Kagaru, Knapp, Knapp Acidic Phase, Lowood, Mundoolun, Pine Vale, Rathdowney, Richards, Stockleigh* and *Woollaman.* With the exception of *Richards*, all soils are shared with the Gatton Sandstones and while characteristics are similar they may vary due to changes in lithology, landform and land use (Table 47).

Table 47. Field-measured properties of soils developed on Koukandowie Formation sediments

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Birnam (Bi)	S-Acid to M-Acid	M-Acid to MO-Alk	VL	L	No	M	Mod
Cedar Vale (Cv)	M-Acid	S-Acid	VL	VL	No	L	Low
Dulbolla (Db)	M-Acid to SL-Acid	M-Acid to MO-Alk	L	M	No	VH	Mod
Dulbolla Sodic Phase (DbSp)	M-Alk to MO-Alk	M-Alk to S-Alk	L	H	Yes	L	Low
Flanagan (Fl)	S-Acid to M-Acid	VS-Acid to M-Acid	VL-L	L	No	M-H	Mod
Glenoake (Gl)	M-Acid to N	SL-Acid to S-Alk	L	L	No	M	Mod
Gould (Gd)	S-Acid to SL-Acid	VS-Acid to SL-Acid	L	L	No	H	Mod
Hardgrave (Ha)	M-Acid	SL-Acid to S-Alk	VL	L	No	H	Mod
Kagaru (Ka)	M-Acid	M-Alk to S-Alk	L	M	No	VH	High
Knapp (Kn)	M-Acid	M-Acid	L	L	No	M	Mod
Knapp Acidic Phase (KnAp)	N	VS-Acid	VL	VL	No	M	Low
Lowood (Lw)	S-Acid to SL-Acid	S-Acid to MO-Alk	VL	L	Yes	L	Low
Mundoolun (Mu)	M-Acid	M-Acid to SL-Acid	VL	L	No	M	Low
Pine Vale (Pv)	M-Acid	VS-Acid to SL-Acid	VL	VL-L	No	M	Low
Rathdowney (Ra)	M-Acid to SL-Acid	M-Acid to N	VL-L	M	No	M	Low
Richards (Ri)	M-Acid to N	M-Acid to M-Alk	L	M	Rare	H	High
Stockleigh (St)	M-Acid	SL-Acid to MO-Alk	L	M	No	M	Low
Woollaman (Wm)	M-Alk to MO-Alk	M-Acid to SL-Acid	L	L	No	VL	Poor

Birnam, Dulbolla Sodic Phase, Flanagan, Gould, Knap Acidic Phase and *Pine Vale* are all strongly or very strongly acidic soils and will have colloidal surfaces likely be dominated by less desirable ions such as aluminium, manganese and iron while plant growth elements such as nitrogen, phosphorus and potassium will be less available. The remaining range from slightly acidic to neutral or mildly alkaline and will probably have a wider range and higher availability of nutrients.

Surface salinities for all Gatton Sandstone soils are very low to low, while subsoil conductivity increases to moderate in *Dulbolla, Dulbolla Sodic Phase, Kagaru, Pine Vale, Richards* and *Stockleigh.*

Sodicity is consistently strong in *Dulbolla Sodic Phase* and *Lowood* soils with others such as *Rathdowney* and *Richards* occasionally sodic.

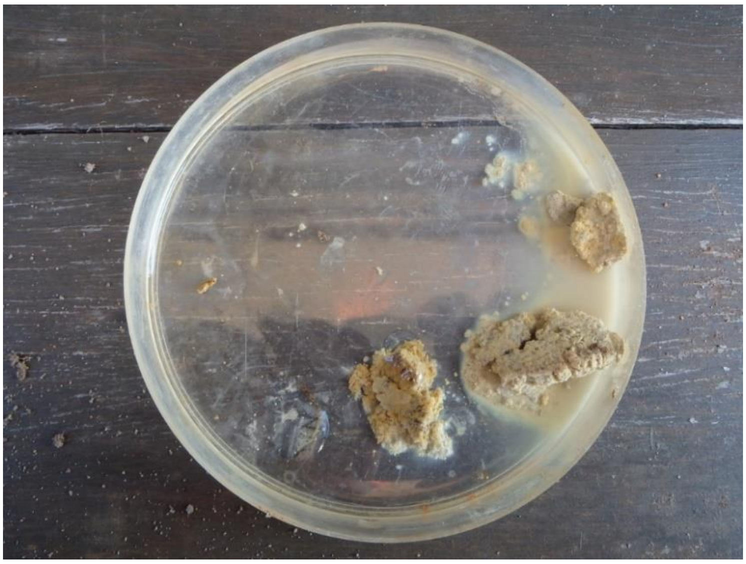


Figure 60. Example of field dispersion testing. Note dispersed clay "cloud" surrounding peds on the right.

Available moisture (PAWC) varies from very low to low in sodic (root access to subsoil moisture restricted by sodicity) and very sandy soils (*Woollaman*) to very high in deep, clay dominated and non-sodic *Dulbolla* and *Kagaru* soils. Remaining soils have a moderate ability to retain moisture.

Fertility, as estimated by the Likely Fertility score, is generally poor to low affected by low soil pH and low clay content, both of which are evident in *Woollaman* soils. Many of the texture contrast (duplex) soils also fall into the lower fertility categories due largely to their sandy A horizons with probable low or very low CEC values. In contrast the higher clay percentage and higher pH soils such as *Kagaru,* and *Richards* are likely to have high fertility. The remaining soils are likely to be of moderate fertility.

10.5.4 Soil formed on Walloon Coal Measures

The only SPC sampled for laboratory analysis on the Walloon Coal Measures was *Gould*. Selected, relevant chemical properties of this soil are presented in Table 48 and Figures 61 and 62.

Table 48. Selected properties of a laboratory analysed *Gould* soil formed on Walloon Coal Measures

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. ratio	CEC/ clay%	Ca:Mg ratio
Gould (MFM Site 425)									
0-0.1	5.6	0.07	24	33	11	3.2	-	0.3	0.8
0.2-0.3	5.9	0.03	<20	43	14	5.9	0.37	0.3	0.4
0.5-0.6	5.2	0.57	897	65	32	17	0.44	0.5	0.4
0.8-0.9	5.0	1.03	1500	70	40	23	0.69	0.6	0.4
1.1-1.2	5.1	1.27	1910	77	47	26	0.95	0.6	0.4
1.4-1.5	5.1	1.36	2080	-	-	-	-	-	-

This deep *Gould* soil has a medium acid surface pH (5.6-5.9) but a strongly to very strongly acid (pH 5.0-5.2) subsoil. Low pH values such as these may lead to elemental toxicities (e.g. manganese and aluminium) but may also prevent roots exploring below 0.3 m. Salinity is moderate at 0.5-0.6 m (0.57 dS/m) then increases to very high levels (1.36 dS/m) at lower depths, with chloride levels following the same pattern (897-2080 mg/kg). Growth of salt sensitive plants (e.g. beans and avocado) will be affected at these salt concentrations. ESP, dispersion ratio and sodium concentrations also increase with depth (Figure 61), with the profile becoming sodic at 0.2-0.3 m and becoming strongly sodic (>15%) below that. Subsoil drainage and permeability at this location will be severely restricted as a result.

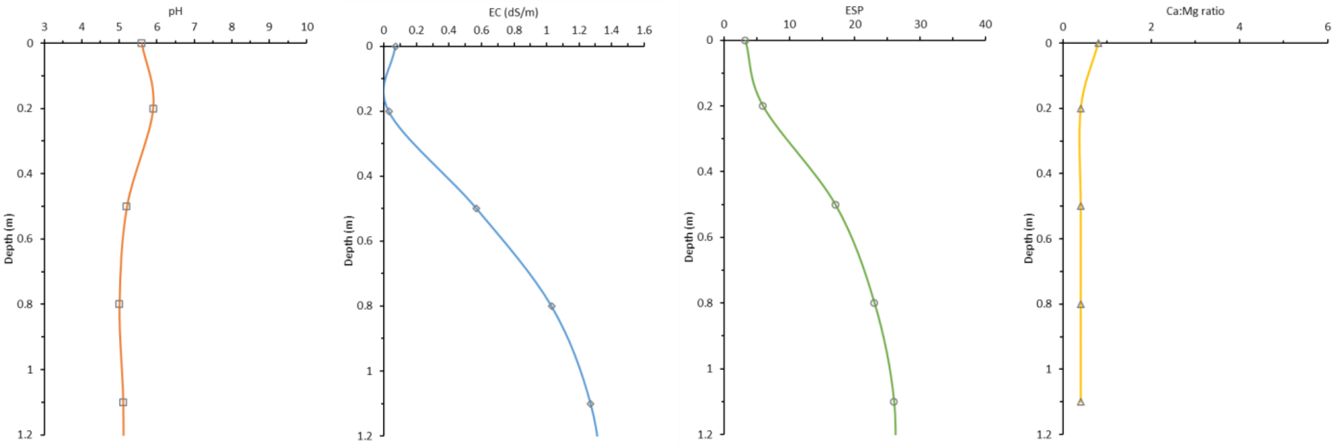


Figure 61. Profile pH, EC, ESP and Ca:Mg for a *Gould* soil developed on Walloon Coal Measures

Clay content (Figure 62) is high at the surface and increases to very high with depth, as would be expected in a soil profile that grades from a light clay surface to medium clay subsoil. CEC (Figure 62) follows this trend rising from moderate to high at the surface to very high (>30) in the subsoil. Clay activity (<0.7) and Ca:Mg ratios (<0.5) suggest an illite based clay lattice that is magnesium dominated (followed by calcium then sodium). Given the magnesium dominated Ca:Mg ratios and the levels of sodium present there is likely to be little exchange surface left for other valuable nutrients. In fact, below 0.5m depth exchangeable potassium at this site falls below 1%.

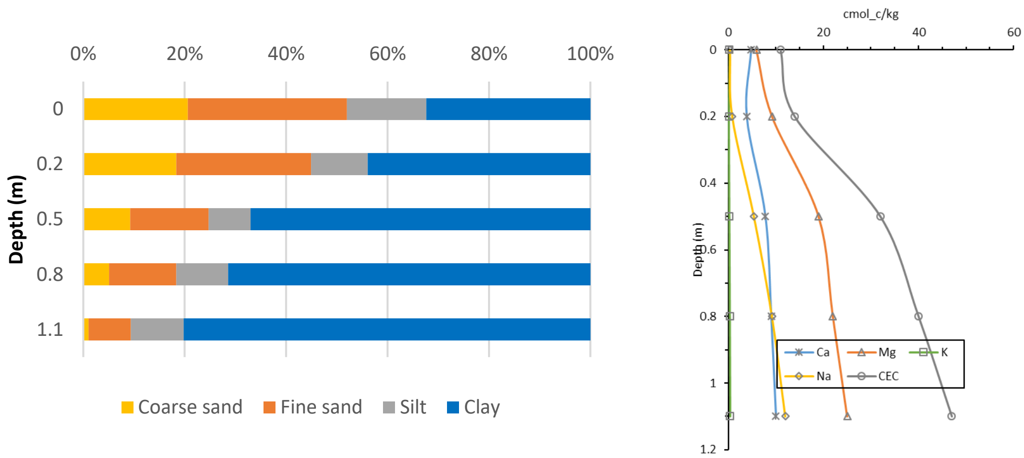


Figure 62. Particle size analysis (left), CEC and cations (right) for a *Gould* soil

Other soils formed on the Walloon Coal Measures are *Brabazon, Brennan, Drynan, Edendale, Josephville, Kagaru, Laravale, Lillydale, Lillydale Acidic Phase, Nindooinbah, Nindooinbah Deep Phase, Saville* and *Woollaman* (Table 49).

Table 49. Field-measured properties of soils developed on the Walloon Coal Measures

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Brabazon (Bz)	M-Acid to SL-Acid	SL-Acid to S-Alk	VL	L	No	H	Mod
Brabazon Acidic Phase (BzAp)	S-Acid to SL-Acid	S-Acid	VL	L	No	L	Low
Brennan (Be)	S-Acid to SL-Acid	VS-Acid to M-Acid	VL	L	Rare	H	Low
Drynan (Dn)	M-Acid to SL-Acid	S-Acid to SL-Acid	VL	M	No	M	Low
Edendale (Ed)	M-Acid to SL-Acid	M-Acid to MO-Alk	VL	L	No	H	High
Josephville (Jo)	M-Acid to N	N to MO-Alk	VL	VL	No	M	High
Kagaru (Ka)	M-Acid to N	M-Acid to S-Alk	L	H	No	VH	High
Laravale (Lv)	M-Acid	N to S-Alk	VL	H	No	VH	Mod
Lillydale (Ld)	SL-Acid to N	N to MO-Alk	VL	L	No	VH	Mod
Lillydale Acidic Phase (LdAp)	S-Acid to M-Acid	S-Acid to SL-Acid	VL	M	No	H	Mod
Nindooinbah (Ni)	S-Acid to SL-Acid	SL-Acid to S-Alk	VL	L	No	M	Mod
Saville (Sv)	M-Acid	SL-Acid to S-Alk	L	H	Yes	L	Low
Nindooinbah Deep Phase (NiDp)	M-Acid to SL-Acid	SL-Acid to S-Alk	M	M	No	VH	Mod
Woollaman (Wm)	M-Acid to SL-Acid	M-Acid to SL-Acid	L	L	No	VL	Poor

The majority of soils formed on the Walloon Coal Measures have an acidic surface pH with *Brabazon, Brennan, Lillydale Acidic Phase* and *Nindooinbah* having the lowest surface pH. Others such as *Drynan, Edendale, Laravale, Saville, Nindooinbah Deep Phase* and *Woollaman* have surfaces with medium to slight acidity. The remaining soils including *Josephville, Kagaru* and *Lillydale* a have slightly acidic to neutral surface pH.

Subsoil pH ranges from very strongly and strongly acid (*Brabazon Acidic Phase, Brennan, Drynan* and *Lillydale Acidic Phase*) to strongly alkaline (*Kagaru, Laravale, Nindooinbah, Nindooinbah Deep Phase* and *Saville*). Many of the subsoil pH's increase with depth so that soils such as *Edendale* have an upper subsoil pH that is moderately acid but grades to moderately alkaline at depth. Lithology appears to be a factor in soil pH, with siltstone generating higher pH soils.

Low pH reduces the ability of soils to retain desirable nutrients (such as nitrogen, phosphorus and potassium) as they are replaced in high concentrations by elements such as aluminium, manganese and iron. However, high pH (>8.5) also restricts the balance of available nutrients and some of these soils (*Brabazon, Kagaru, Laravale, Nindooinbah* and *Nindooinbah Deep Phase* – largely where siltstone is the lithology) may suffer restricted availability of some micronutrients like zinc, magnesium and boron.

In other cases such as *Saville,* high pH correlates with high sodium concentrations (sodicity) and poor physical conditions (Baker and Eldershaw 1993). Additionally, calcium carbonates (solid phase calcium) may form above pH 8.5, as was observed in *Brabazon, Kagaru, Laravale, Nindooinbah, Saville* and *Nindooinbah Deep Phase*.

Surface salinity is either very low or low with the exception of *Nindooinbah Deep Phase* which is moderate (0.25 to <0.5 dS/m). Subsoil conductivity is generally low to moderate (0.5 dS/m), however, values for *Kagaru, Laravale* and *Saville* are high (0.5 to <1.0 dS/m) and may impede root growth of sensitive plants. Salinity outbreaks were identified on the Walloon Coal Measures in the Upper Logan River associated with *Nindooinbah* and *Nindooinbah Deep Phase* soils that contact poorly drained alluviums (see Land Degradation section). Sodicity is not common in these soils with the exception of the *Saville* soils or occasionally *Brennan*.

Due to the low sodicity and high clay content of the soils formed on Walloon Coal Measures their available soil water (PAWC) is moderate to high or very high (>50 mm/m). However, PAWC is very low for *Woollaman,* due to its sandy textures, and low for *Saville* because of the sodic B horizon which limits root penetration and therefore moisture access.Fertility of these soils is generally moderate to high thanks to clay percentage (as measured by texture) and neutral to mildly alkaline pH. However, some soils (*Brennan* and *Drynan*) have lower fertility due to the stronger acidity of their B horizons.

10.6. Soils developed on the Beaudesert Beds

The only SPC sampled for laboratory analysis on Beaudesert Beds geology is the sodic *Saville*. Selected, relevant chemical properties of *Saville* are presented in Table 50 and Figures 63 and 64.

As Table 50 and Figure 63 show, the *Saville* soil at LARA Site 9017 has a slightly acidic surface with a strongly acidic upper B horizon abruptly changing to a neutral or mildly alkaline and sodic subsoil. These characteristics match those described during field description of *Saville* soils. Both EC and chloride values increase steadily with depth to have moderate salinity in the upper B horizon but high salinity in the lower B horizon, following the pattern of ESP and dispersion ratio. Clay percentage is similar to other texture contrast soils tested in that the surface is low (<20%) but increase abruptly to high (>45%) once the B horizon is encountered (Figure 64). CEC reflects the clay content pattern and increases steadily with depth to a maximum of 32, while clay activity ratios suggest a clay type which is illite (non-expanding clay) based. However, looking at the magnesium dominated Ca:Mg ratios (Figure 64) and the levels of sodium present, there is likely to be little exchange surface left for other, more valued ions. This combined with its poor drainage and permeability characteristics (as it is strongly sodic) and salinity make this *Saville* soil unsuited to agriculture.

Table 50. Selected properties of a laboratory analysed sodic *Saville* soil formed on Beaudesert Beds

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. ratio	CEC/ clay%	Ca:Mg ratio
Saville (LARA Site 9017)									
0-0.1	6.26	0.09	54	19	11	6.9	0.54	0.6	1.2
0.25-0.35	5.80	0.23	331	48	21	20	0.86	0.4	0.5
1.1-1.2	7.32	0.93	1507	57	32	32	1.1	0.6	0.5

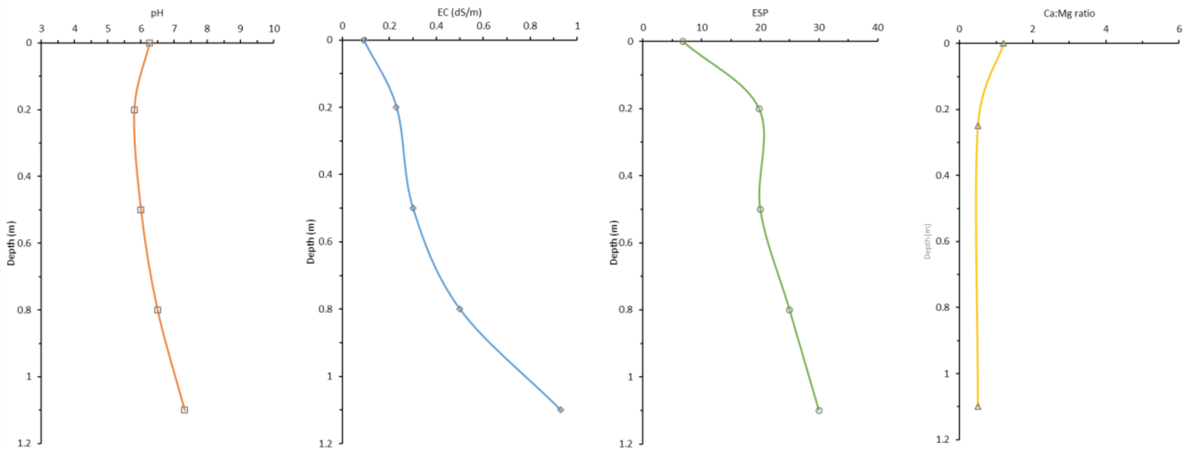


Figure 63 Profile pH, EC, ESP and Ca:Mg for a *Saville* soil developed on Beaudesert Beds

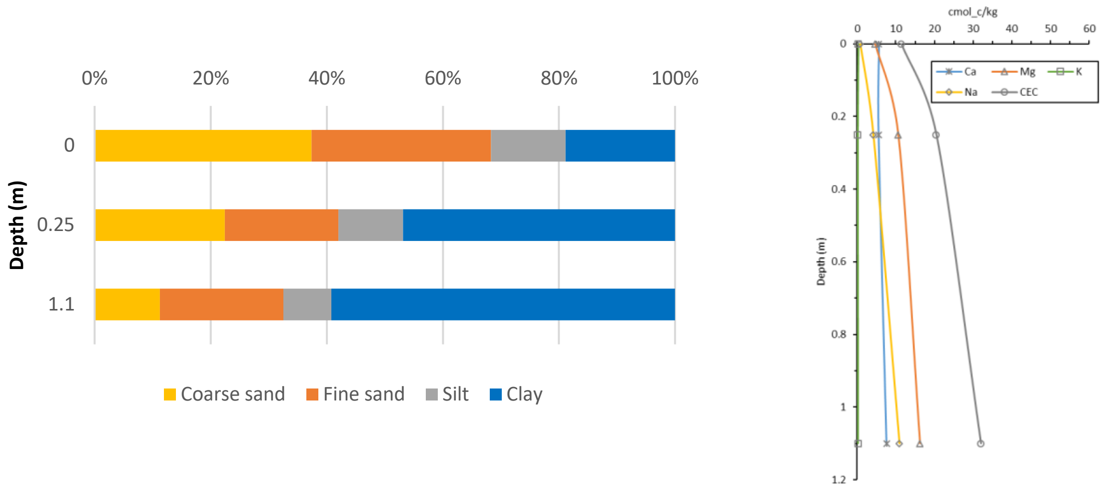


Figure 64. Particle size analysis (left), CEC and cations (right) for a *Saville* soil

Other soils formed on the Beaudesert Beds are *Brabazon, Brennan, Drynan, Tartar Shallow Phase, Gould, Josephville, Kagaru, Laravale, Nindooinbah, Sarabah, Nindooinbah Deep Phase, Telemon and Woollaman* (Table 51).

Table 51. Field-measured properties of soils developed on the Beaudesert Beds

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Brabazon (Bz)	S-Acid to SL-Acid	S-Acid to S-Alk	VL	L	No	H	Mod
Brennan (Be)	M-Acid to N	VS-Acid to SL-Acid	M	EH	No	H	Low
Drynan (Dn)	SL-Acid	VS-Acid to M-Acid	VL	M	No	M	Low
Gould (Gd)	SL-Acid	M-Acid to N	VL	L	No	H	Mod
Josephville (Jo)	M-Acid to N	SL-Acid to MO-Alk	VL	VL	No	M	High
Kagaru (Ka)	M-Acid to N	M-Acid to S-Alk	L	H	No	VH	High
Laravale (Lv)	M-Acid	N to S-Alk	M	M	No	VH	Mod
Nindooinbah (Ni)	S-Acid to N	SL-Acid to S-Alk	VL	L	No	M	Mod
Sarabah (Sa)	SL-Acid	SL-Acid to M-Alk	VL	VL	No	L	Mod

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Nindooinbah Deep Phase (NiDp)	S-Acid to SL-Acid	SL-Acid to M-Alk	VL	H	No	M	Low
Tartar Shallow Phase (TtSp)	M-Acid to N	M-Acid to S-Alk	VL	L	No	H	High
Telemon (Tm)	M-Acid to SL-Acid	M-Acid to MO-Alk	VL	VL		M	High
Woollaman (Wm)	M-Acid to SL-Acid	M-Acid to SL-Acid	L	L	No	VL	Poor

The Beaudesert Beds are a complex geology unit. While many of the soils formed on the sandstones and siltstones of Gatton Sandstone, Koukandowie Formation and Walloon Coal Measures geologies are present here, also present are soils derived from Neogene basalts and other sediments of basic or intermediate rocks (*Tartar Shallow Phase, Sarabah* and *Telemon*) that have more in common with the younger geologies beneath.

As Table 46 shows, surface soils are generally moderately acidic to neutral (pH 6.0-7.0) with the exception of the potentially (not in all occurrences) strongly acidic or very strongly acidic surface of *Brabazon, Nindooinbah* or *Nindooinbah Deep Phase* soils. Subsoil pH of the basalt derived or influenced soils has an upward trend with depth from moderately acidic (pH 6.0) to mildly to strongly alkaline (pH 7.5-8.5). However, the sandstone and siltstone based soils have more acidic pH's with only some having ranges reaching neutral or alkaline levels (*Brabazon, Josephville, Kagaru, Laravale* and *Nindooinbah*). Of note is the consistent, slight to moderate acidity of the *Woollaman* soils across geologies. Overall the availability of nutrients in these soils is unlikely to be greatly influenced by pH.

EC values for surface soils are very low or low with the exception of *Brennan* and *Laravale* where levels are moderate. However, subsoil levels vary greatly from very low or low (*Brabazon, Tartar Shallow Phase, Gould, Josephville, Sarabah* and *Telemon*) to high and extremely high (*Brennan, Kagaru* and *Nindooinbah Deep Phase)*. High EC is a feature of *Kagaru* soils.

With the exception of *Woollaman* (sandy Tenosols), *Saville* (sodic) and *Sarabah* (shallow) all soils on the Beaudesert Beds have moderate to very high moisture holding capacity (PAWC >50 mm/m).

The likely fertility of these soils is largely predictable and linked to parent material. Moderate to high fertility is likely in *Tartar Shallow Phase, Sarabah* and *Telemon* soils (basalt derived) while low to poor fertility is expected in *Brennan, Drynan, Nindooinbah Deep Phase* and *Woollaman* soils developed on sandstone with low pH and/or low clay content.

10.7. Soils developed on Neogene volcanics

SPC's sampled to represent soils developed on Neogene volcanics are *Glenapp* and *Tamborine*, both basalt derived. Selected, relevant chemical properties of these soils are presented in Table 52 and Figures 65 and 66.

The deep black *Glenapp* Vertosols are located on lower slopes and foot slopes and are the most likely of the non-colluvial basalt soils to be used for agriculture. Both samples have slightly acidic surface soils which quickly change to moderately to strongly alkaline and calcic subsoils. EC values, while not of concern, reach moderate levels (>0.3 dS/m) at depths greater than 0.6 m, however, chloride levels for LARA Site 9004 don't appear to follow the EC trend, indicating that calcium carbonates may be contributing to the elevated EC. ESP and dispersion ratios reach sodic threshold levels below 0.6m at LARA Site 9004 and below 1.2 m at LARA Site 9007. These mild values combined with their depth are not expected to significantly impede crop or pasture growth but there may be some impact on drainage and permeability. As would be expected for a Vertosol, clay percentage (Figure 65), CEC and clay activity ratio are high to very high. Conversely, Ca:Mg ratios are below adequate and magnesium will dominate the cation exchange.

Table 52. Selected properties of some laboratory analysed soils formed on Neogene basalts

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. ratio	CEC/ clay%	Ca:Mg ratio
Glenapp (LARA Site 9004)									
0.1-0.2	6.63	0.07	<20	53	45	3	0.52	0.9	1.2
0.5-0.6	8.36	0.32	53	57	49	6	0.57	0.9	0.9
0.8-0.9	9.01	0.28	21	28	32	10	0.88	1.1	0.8
Glenapp (LARA Site 9007)									
0-0.05	6.22	0.16	73	32	41	<1	0.51	1.3	1.5
0.2-0.3	7.00	0.07	41	55	45	2	0.52	0.8	1.6
0.5-0.6	8.26	0.17	93	50	46	4	0.60	0.9	1.6
0.8-0.9	8.58	0.29	167	35	43	6	0.70	1.2	1.4
1.1-1.2	8.52	0.30	275	33	42	6	0.78	1.3	1.5
1.4-1.5	8.28	0.32	406	30	40	6	0.83	1.3	1.5
Tamborine (SOC Site 11)									
0-0.05	5.6	0.18	89	-	-	-	-	-	1.7
0.05-0.1	5.6	0.08	68	40	13	<1	-	0.3	3.5
0.1-0.2	5.8	0.04	34	58	9.3	<1	-	0.2	4.6
0.2-0.3	6.0	0.02	28	71	7.8	<1	-	0.1	5.5
0.5-0.6	6.0	0.02	20	81	6.2	<1	-	0.1	-
0.8-0.9	4.8	0.03	23	71	4.1	1	-	0.1	-
1.1-1..2	4.5	0.04	37	74	8.1	<1	-	0.1	-
1.4-1.5	4.5	0.04	46	62	9.4	<1	-	0.2	-

In contrast, the deep red *Tamborine* Ferrosols and Dermosols sampled have an acidic reaction trend starting with a medium acid surface but grading to a very strongly or extremely acid subsoil and show very little salinity (<0.1 dS/m). Additionally, *Tamborine* has high to very high clay percentage values (Figure 65) paired with only low to moderate CEC (Figure 66). The result is a very low clay activity ratio (<0.3) for most of the profile indicating that a mix of poorer quality kaolinite clays and non-expanding illite clays prevails. ESP percentages are low and may be due to a leached environment which has removed sodium (basalt likely to be low to begin with) as exchangeable sodium levels are <1% of CEC. Ca:Mg ratios are within an acceptable range (1.7 to 5.5) and indicate a favourable balance of cations on the limited CEC, however other nutrients may still be deficient.

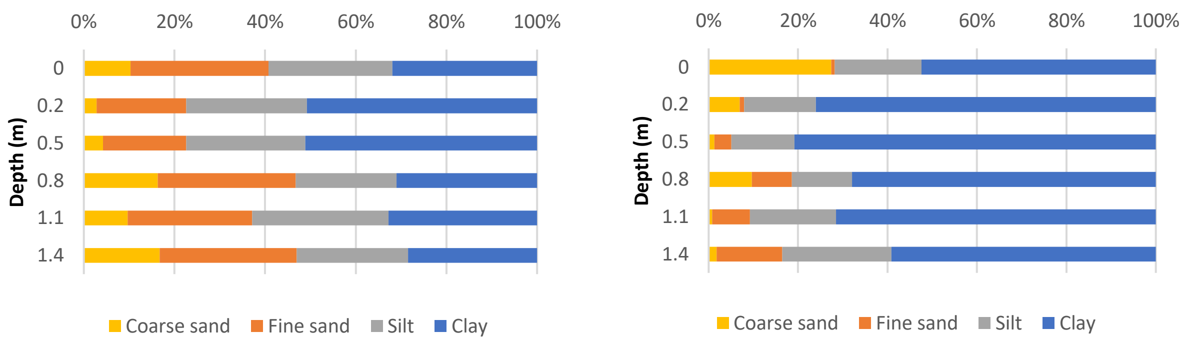


Figure 65. Particle size analysis for *Glenapp* (left) and *Tamborine* (right)

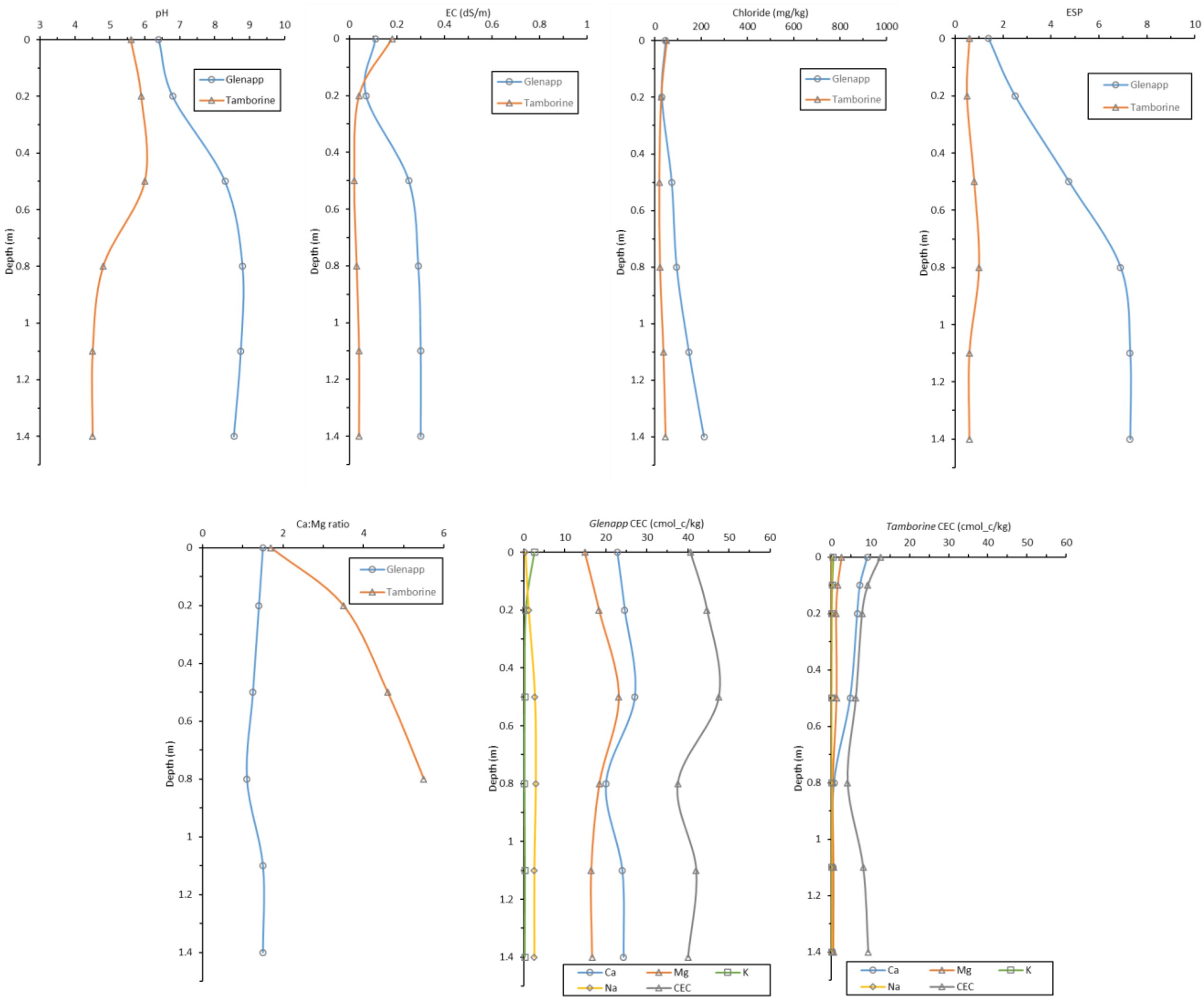


Figure 66. Profile pH, EC, chloride, ESP, Ca:Mg ratio, CEC and cations for soils developed on Neogene basalt

Other soils formed on the Neogene volcanics are *Barney, Cainbable, Canungra, Chinghee, Tartar Shallow Phase, Gorman, Sarabah Tenosol Variant, Lindesay, Palen, Philp, Sarabah, Tartar, Telemon* and *Wonglepong* (Table 53).

This group of soils are formed on basic (basalt) and intermediate to acid (rhyolite, rarely trachyte) igneous rocks and the soil properties generally follow this division.

With little exception, the basalt derived soils (the majority here) have surface pH's that are moderately acidic to neutral (pH 6.0-7.5) with subsoils ranging from slightly to moderately acidic at the top of the B horizon to moderately, strongly or very strongly alkaline with increasing depth. Therefore, if any nutrient limitations arise from pH in these soils it will be at the upper limit of pH >8.5. The notable exception is *Tamborine* with a very strongly to medium acid subsoil.

Remaining soils in this group are derived from rhyolite or trachyte (*Barney* and *Philp*) and tend to be of lower pH (higher acidity), mirroring the inherent acidity of the rocks themselves. Surfaces tend to be slightly to moderately acidic (pH 6.0-6.5) while subsoils are very strongly to moderately acidic (pH 4.5-6.0). These levels indicate that some micronutrients may be unavailable (e.g. where pH is very strongly or strongly acidic (pH <5.5) and that displacement of desirable ions by toxic levels of manganese iron and aluminium may have occurred.

Surface and subsoil salinity (EC) across all soils derived from Neogene volcanics is very low to low (rarely moderate), reflecting the lack of salts in their parent materials. Similarly sodicity is very low or non-existent.

Due to the mostly clay textures of these soils, they generally have moderate to very high PAWC values and moderate to high fertility. However, *Barney* soils (formed on rhyolite/trachyte) have poor likely fertility as a result of their low pH.

Table 53. Field-measured properties of soils developed on the Neogene volcanics

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Barney (Ba)	M-Acid to SL-Acid	M-Acid to S-Acid	L	L	No	VL	Low
Cainbable (Ce)	M-Acid to N	M-Acid to N	VL	VL	No	L	Mod
Chinghee (Ch)	M-Acid to M-Alk	M-Acid to S-Alk	L	L-M	No	H-VH	High
Gorman (Go)	M-Acid	M-Alk	VL	L	No	L	Mod
Sarabah Tenosol Variant (SaTv)	M-Acid	M-Acid	VL	VL	No	L	Mod
Lindesay (Li)	M-Acid to N	M-Acid to S-Alk	VL-L	L-M	No	VH	High
Palen (Pa)	M-Acid to M-Alk	M-Acid to S-Alk	L	M	No	VH	High
Philp (Pp)	M-Acid	VS-Acid to N	L	L	No	H	Mod
Sarabah (Sa)	M-Acid to M-Alk	M-Acid to M-Alk	VL	VL	No	VL-L	Mod
Tartar (Tt)	M-Acid to SL-Acid	M-Acid to S-Alk	VL	VL	No	VH	High
Tartar Shallow Phase (TtSp)	M-Acid to N	M-Acid to S-Alk	VL	L	No	M	High
Telemon (Tm)	M-Acid to SL-Acid	M-Acid to MO-Alk	VL	VL	No	M	High
Wonglepong (Wo)	M-Acid	SL-Acid	VL	VL	No	M	High

10.8. Soils developed on Neogene sediments

Soils formed on the Neogene sediments are *Brabazon* and *Dunsinane*. While both these soils are formed on Neogene (Tertiary) sediments they have very different field chemical properties (Table 54). Surface pH is very similar, moderately acidic to neutral, however, *Brabazon* has a very strongly acidic subsoil while *Dunsinane* maintains its moderately acidic to neutral levels. This is likely to result in the clay surfaces of *Brabazon* being dominated, at potentially toxic levels, by aluminium, manganese and iron while those of *Dunsinane* having a wider range of more available nutrients present.

Table 54. Field-measured chemistry of soils developed on Neogene sediments

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely fertility
Brabazon Acidic Phase (BzAp)	M-Acid	VS-Acid	VL	M	No	H	Low
Dunsinane (Ds)	M-Acid to N	M-Acid to N	VL	L	No	M	Mod

Surface and subsoil EC are below any level of concern for both soils, as is sodicity. Either soil has an acceptable level of soil water holding ability (PAWC), however, the PAWC of *Dunsinane* is limited by its shallow depth. *Dunsinane* has a moderate likely fertility, however, the likely fertility of *Brabazon* is impacted by its low pH and the probable reduction in favourable nutrients that infers.

10.9. Soils developed on Neogene to Pleistocene colluvium

SPC's sampled to represent soils developed on Neogene to Pleistocene colluvium are *Glenapp* and *Wonglepong*. Selected, relevant properties of these soils are presented in Table 55 and Figures 67 and 68.

Glenapp and *Wonglepong* soils are physically similar in many ways apart from depth (*Wonglepong* are shallower) and this similarity extends to soil chemistry. Both soils have slightly acidic surfaces that grade to neutral and have strongly alkaline subsoils at depths below 0.3 m, which are frequently calcic. Salinity is negligible but *Glenapp* exhibits some moderate conductivity (0.53 & 0.57 dS/m) at 0.8 m and its chloride levels follow this pattern also. All samples tested show sodicity from the 0.8-0.9 m depth, ranging from an ESP of 5% (slightly sodic) in the *Wonglepong* sample to 8% and 13% (sodic) in the 2 *Glenapp* samples. Dispersion ratios of 0.7 to 0.8 support the possibility of dispersion occurring at depth. Clay percentage (>30) (Figure 68), CEC (≥40) (Figure 67) and clay activity ratios are high or very high (>0.8) across all samples.

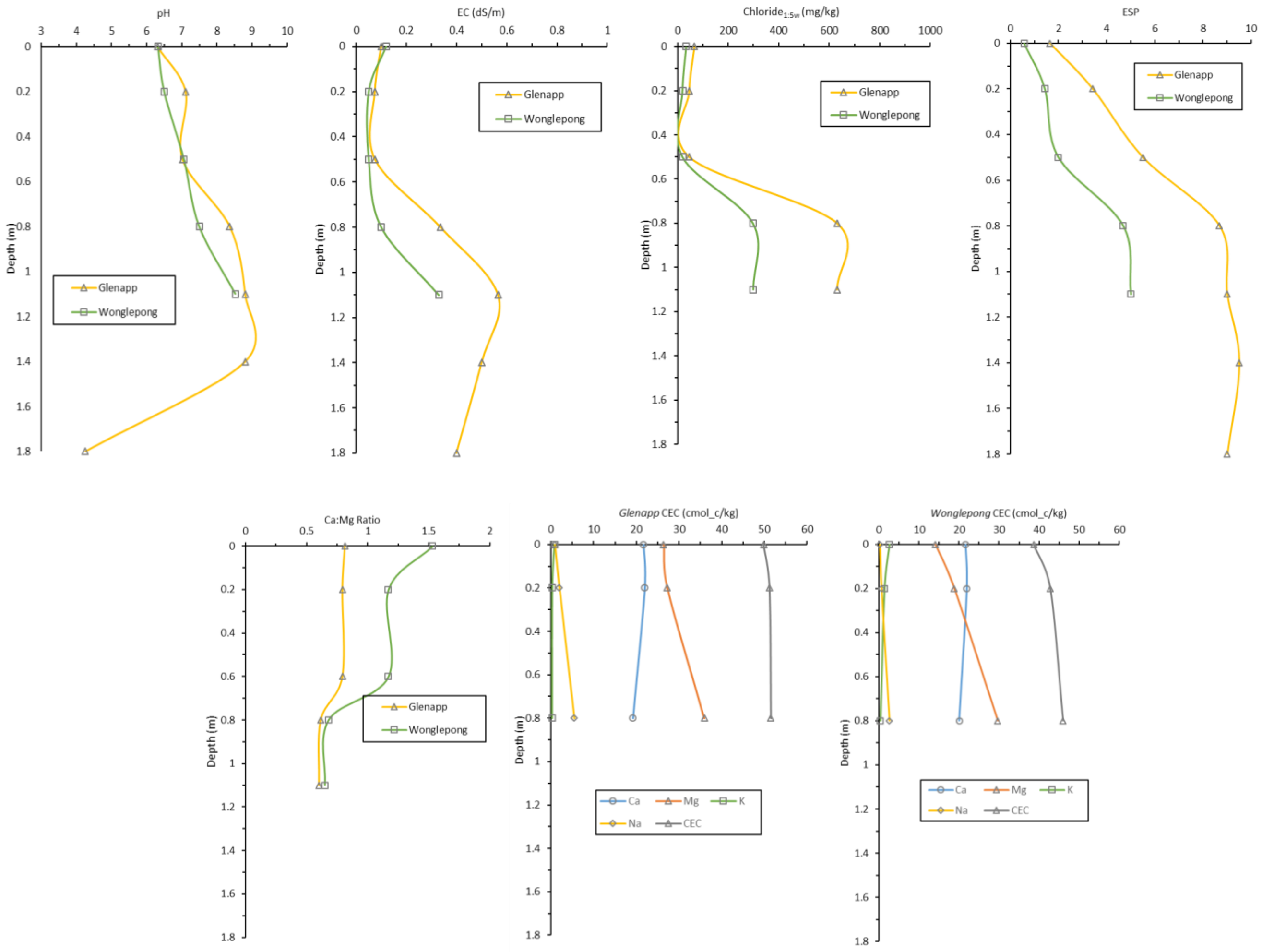
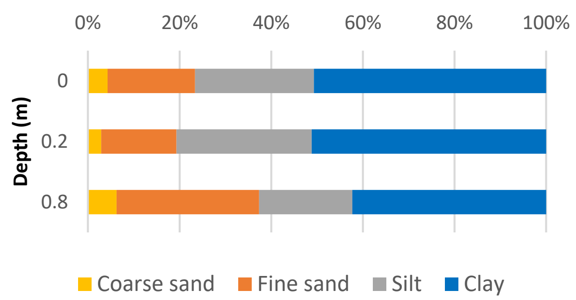


Figure 67. Profile pH, EC, Chloride, ESP, Ca:Mg ratio, CEC and cations for soils developed on Neogene to Pleistocene colluvium

These indicators suggest clay types are 2:1 expanding montmorillonite and there are many available exchange sites on clay faces. However, the Ca:Mg ratios (0.4-1.5) of all samples mean that these exchange sites are dominated by magnesium and some, where the ratio is <0.5, maybe more prone to dispersion e.g. 0.8-0.9 m in *Glenapp* sample from LARA Site 9016. It should be noted that dispersion was not observed in either soil during field testing and that many of the sites visited were currently, or had recently been, used for agricultural cultivation.

Table 55. Selected properties of some soils developed on Neogene to Pleistocene colluvium

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. ratio	CEC/ clay%	Ca:Mg ratio
Glenapp (LARA Site 9008)									
0-0.05	6.42	0.13	111	60	54	2	0.60	0.9	0.9
0.2-0.3	7.71	0.11	70	64	63	4	0.64	1.0	0.9
0.8-0.9	8.73	0.57	588	28	43	13	0.77	1.5	0.9
Glenapp (LARA Site 9016)									
0-0.09	6.19	0.07	<20	45	46	1	0.67	1.0	0.7
0.2-0.3	6.53	0.04	<20	39	40	3	0.69	1.0	0.7
0.8-0.9	8.50	0.53	675	61	60	8	0.78	1.0	0.4
Wonglepong (LARA Site 9010)									
0-0.1	6.32	0.12	34	31	39	<1	0.55	1.3	1.5
0.2-0.3	7.06	0.05	<20	49	43	1	0.62	0.9	1.2
0.8-0.9	8.53	0.33	299	49	46	5	0.76	0.9	0.7



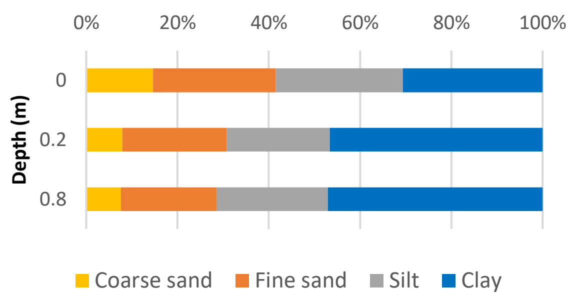


Figure 68. Particle size analysis for *Glenapp* (left) and *Wonglepong* (right)

Other soils formed on Neogene to Pleistocene colluvium are *Ernest, Palen* and *Shaws*. *Palen* and *Shaws* are derived from basalt or basalt like (greenstone) materials and therefore have chemical characteristics similar to the basalt based soils above - strongly alkaline subsoils (possible with the associated elemental deficiencies), low salinity, absence of sodicity and high or very high PAWC and likely high fertility (Table 56). *Ernest* soils are formed from sandstone or rhyolite sources and this is reflected in their stronger subsoil acidity, potential sodicity and associated lower likely fertility. Its clay textures still ensure that PAWC values will be high.

Table 56. Field-measured properties of soils developed on Neogene and Pleistocene colluvium

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely Fertility
Ernest (Er)	M-Acid	VS-Acid to N	VL	M	Rare	H	Mod
Palen (Pa)	M-Acid to N	N to S-Alk	L	L	No	VH	High
Shaws (Sh)	M-Acid to SL-Acid	M-Acid to S-Alk	VL	M	No	VH	High
Glenapp (Gp)	SL-Acid to N	SL-Acid to S-Alk	L	M	No	VH	High
Wonglepong (Wo)	SL-Acid to N	N to VS-Alk	L	L	No	H	High

10.10. Soils of the Quaternary (Pleistocene to Holocene) alluvial plains

SPC's sampled to represent soils developed on alluvial plains are *Basel*, *Bell (SEQ)*, *Blenheim*, *Bremer Buried Phase*, *Gunyah*, *Hooper*, *Kilmoylar*, *Sippel* and *Waterford*. Selected, relevant chemical properties of these soils are presented in Table 57 and Figures 69 to 75.

Table 57. Selected properties of soils developed on Holocene and Pleistocene alluvial plains

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. Ratio (R1)	CEC/ clay%	Ca:Mg ratio
Basel (LARA Site 9014)									
0.03-0.13	5.82	0.04	<20	53	30	2	0.59	0.6	0.75
0.20-0.30	6.58	0.03	<20	59	33	3	0.72	0.5	0.71
0.80-0.90	7.78	0.29	423	59	33	6	0.83	0.6	0.69
Basel (SEQ Site 402)									
0-0.1	6.1	0.07	24	40	50	<1	0.49	1.3	1.1
0.2-0.3	7.0	0.04	<20	49	54	2	0.60	1.1	0.9
0.5-0.6	7.7	0.07	<20	52	56	3	-	1.1	0.8
0.8-0.9	8.5	0.13	34	52	57	5	0.81	1.1	0.7
1.1-1.2	8.8	0.17	90	49	53	7	-	1.1	0.6
1.4-1.5	8.8	0.22	184	-	-	-	-	-	-
Bell (SEQ) (LARA Site 9001)									
0-0.1	5.54	0.26	338	21	13	2	0.64	0.6	1.8
0.2-0.3	6.2	0.1	129	24	14	1	0.50	0.6	2.2
0.5-0.6	6.84	0.12	63	49	29	5	0.43	0.6	3.5
0.8-0.9	7.18	0.12	79	40	30	5	0.45	0.8	4.1
1.1-1.2	7.39	0.12	77	35	25	5	0.52	0.7	4.4
1.4-1.5	7.47	0.11	76	28	26	4	0.55	0.9	4.4
Bell (SEQ) (LARA Site 9006)									
0.1-0.2	6.63	0.05	<20	44	39	1	0.6	0.9	2.1
0.4-0.5	7.93	0.04	<20	36	42	2	0.55	1.2	2.4
0.8-0.9	8.12	0.05	<20	25	43	3	0.73	1.7	2.3
Bell (SEQ) (SEQ Site 95)									
0-0.1	6.3	0.05	28	25	20	2	0.56	0.8	1.8
0.2-0.3	6.3	0.03	<20	26	17	2	0.55	0.7	2.1
0.5-0.6	7.0	0.05	42	37	24	3	0.44	0.7	2.0
0.8-0.9	7.7	0.05	47	30	23	4	0.57	0.8	2.1
1.1-1.2	7.3	0.04	32	24	22	4	-	0.9	2.1
1.4-1.5	7.8	0.04	25	-	-	-	-	-	-
Bell (SEQ) (SEQ Site 115)									
0-0.1	5.4	0.17	121	51	41	2	0.45	0.8	0.7
0.2-0.3	6.2	0.16	179	61	43	5	0.57	0.7	0.6
0.5-0.6	7.6	0.57	783	70	50	11	0.68	0.7	0.5
0.8-0.9	8.0	0.79	1170	78	55	14	0.73	0.7	0.5
1.1-1.2	-	-	-	71	48	15	-	0.7	0.5
1.4-1.5	8.0	0.90	1420	-	-	-	-	-	-
Bell (SEQ) (SEQ Site 383)									
0-0.1	6.2	0.08	43	44	57	1	-	1.3	0.9

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. Ratio (R1)	CEC/ clay%	Ca:Mg ratio
0.2-0.3	7.5	0.06	<20	52	52	3	-	1.0	0.8
0.5-0.6	8.3	0.19	194	54	50	7	-	0.9	0.6
0.8-0.9	8.7	0.61	756	54	47	11	0.67	0.9	0.4
1.1-1.2	9.0	0.75	800	43	41	13	-	1.0	0.3
Bell (SEQ) (SEQ Site 393)									
0-0.1	6.3	0.11	50	54	59	2	-	1.1	0.9
0.2-0.3	6.9	0.08	61	48	54	3	-	1.1	1.1
0.5-0.6	7.7	0.19	190	64	60	5	-	0.9	1.1
0.8-0.9	7.8	0.29	289	60	59	7	-	1.0	1.2
1.1-1.2	8.2	0.33	373	52	56	8	-	1.1	1.1
1.4-1.5	8.2	0.38	439	-	-	-	-	-	-
Blenheim (LARA Site 9002)									
0-0.1	6.07	0.10	46	56	51	2	0.49	0.9	1.1
0.21-0.31	6.56	0.08	40	53	49	4	0.59	0.9	1.1
0.5-0.6	7.71	0.26	304	76	65	7	0.65	0.9	1.0
0.8-0.9	8.15	0.58	832	72	62	9	0.63	0.9	1.0
1.1-1.2	8.33	0.84	1211	57	54	11	0.64	0.9	1.0
1.4-1.5	8.25	0.90	1368	48	57	11	0.61	1.2	1.0
Blenheim (LARA Site 9009)									
0-0.05	6.94	0.38	<20	35	43	2	0.57	1.2	3.9
0.2-0.3	6.72	0.07	173	46	38	2	0.58	0.8	1.9
0.5-0.6	7.35	0.12	<20	46	43	2	0.51	0.9	1.8
Blenheim (LARA Site 9009) continued									
0.75-0.85	7.96	0.18	<20	44	43	2	0.48	1.0	2.0
1.1-1.2	8.05	0.19	<20	32	40	4	0.65	1.3	2.0
1.4-1.5	8.27	0.13	<20	33	37	5	0.64	1.1	2.1
Blenheim (LARA Site 9012)									
0-0.1	6.39	0.09	<20	28	31	<1	0.58	1.1	2.1
0.2-0.3	6.7	0.06	<20	33	30	1	0.64	0.9	1.9
0.45-0.55	7.36	0.05	<20	46	41	2	0.66	0.9	1.8
0.8-0.9	8.05	0.11	<20	32	36	2	0.74	1.1	1.8
1.1-1.2	8.23	0.09	<20	36	41	3	0.70	1.2	1.8
1.4-1.5	8.17	0.06	<20	32	42	3	0.74	1.3	1.8
Blenheim (LARA Site 9013)									
0-0.1	6.07	0.09	35	27	31	1	0.61	1.1	1.5
0.2-0.3	6.77	0.04	<20	40	35	3	0.70	0.9	1.5
0.8-0.9	8.53	0.16	161	53	43	9	0.80	0.8	1.3
Blenheim (LARA Site 9015)									
0-0.1	6.44	0.08	32	39	43	1	0.72	1.1	1.4
0.2-0.3	7.06	0.04	<20	43	47	2	0.74	1.1	1.3
0.8-0.9	8.15	0.07	47	57	51	5	0.85	0.9	1.0

Depth (m)	pH	EC (dS/m)	Chloride (mg/kg)	Clay (%)	CEC (cmol/kg)	ESP (%)	Disp. Ratio (R1)	CEC/ clay%	Ca:Mg ratio
Blenheim (LARA Site 9018)									
0-0.1	6.13	0.31	280	53	39	5	0.75	0.7	1.4
0.2-0.3	6.08	0.21	237	55	39	4	0.69	0.7	1.5
0.8-0.9	7.78	0.10	69	57	46	5	0.87	0.8	1.4
Bremer Buried Phase (LARA Site 9003)									
0-0.08	6.31	0.24	89	16	38	<1	0.41	2.4	1.7
02.-0.3	6.98	0.04	<20	21	38	<1	0.42	1.8	2.0
0.8-0.9	7.96	0.03	<20	14	35	2	0.46	2.5	2.1
Gunyah (LARA Site 9005)									
0-0.1	7.37	0.13	<20	14	31	<1	0.46	2.2	1.9
0.2-0.3	6.61	0.03	42	14	27	<1	0.5	1.9	1.9
0.5-0.6	7.41	0.02	<20	16	29	<1	0.57	1.8	2.2
0.8-0.9	7.64	0.02	<20	16	31	<1	0.63	1.9	2.1
1.1-1.2	7.83	0.02	<20	14	27	<1	0.66	1.9	1.9
1.4-1.5	7.78	0.02	<20	23	37	<1	0.64	1.6	1.9
Hooper (LARA Site 9011)									
0-0.1	6.50	0.09	<20	26	37	1	0.65	1.4	1.8
0.5-0.6	7.35	0.03	<20	39	46	1	0.63	1.2	1.8
1.4-1.5	7.91	0.03	<20	23	39	<1	0.60	1.7	1.7
Kilmoylar (LARA Site 9000)									
0-0.1	-	-	-	12	-	-	0.60	-	-
0.2-0.3	6.07	0.01	<20	12	3.7	2	0.76	0.3	2.8
1.1-1.2	6.33	0.01	<20	22	10	2	0.74	0.5	1.9
Kilmoylar (SEQ Site 162)									
0-0.1	7.00	0.10	97	34	18	14	0.65	0.5	0.7
0.2-0.3	5.90	0.04	24	22	11	6	0.31	0.5	1.4
0.5-0.6	7.50	0.65	990	59	28	29	0.94	0.5	0.5
0.8-0.9	7.00	0.36	456	62	29	34	0.94	0.5	0.4
1.1-1.2	5.7	0.91	1440	64	28	36	-	0.4	0.4
1.4-1.5	5.80	0.39	420	-	-	-	-	-	-
Sippel **(**SPFD Site 108)									
0-0.1	5.8	0.06	<20	13	7	1	0.68	0.5	2.3
0.2-0.3	6.2	0.02	<20	13	7	1	0.65	0.5	3.1
0.5-0.6	6.5	0.01	<20	23	9	2	0.69	0.4	2.9
0.8-0.9	6.7	0.01	<20	23	11	2	0.68	0.5	2.5
1.1-1.2	6.8	0.02	<20	26	10	2	0.72	0.4	2.2
1.4-1.5	6.9	0.01	<20	24	10	2	0.77	0.4	2.2
Waterford (SEQ Site317)									
0-0.1	5.7	0.04	26	43	11	4	0.41	0.3	2.5
0.2-0.3	5.0	0.02	28	64	16	3	0.46	0.3	1.1
0.5-0.6	4.9	0.11	154	72	25	6	0.42	0.4	0.8
0.8-0.9	5.0	0.24	321	66	31	8	0.36	0.5	0.8
1.1-1.2	5.3	0.37	509	68	37	10	-	0.5	0.8
1.4-1.5	5.8	0.51	709	-	-	-	-	-	-

The *Basel* soils sampled have a neutral to strongly alkaline soil reaction trend (Figure 69), low to moderate electrical conductivity and low chloride values (Figure 70). Sodicity (and therefore likely soil dispersion) is present at depths greater than 0.8 m, as indicated by ESP ≥6 and a dispersion ratio >0.8. Clay percentage is high (>50%) in most horizons (Figure 71), and a moderate to high clay activity ratio suggests that clay composition is likely to be combination of non-expanding illite and expanding montmorillonite, which is supported by their known vertic properties. A calcium/magnesium ratio (Ca:Mg) ranging between 0.6 and 1.1 (ideally >4) infers a dominance of magnesium on exchange surfaces and this may also exacerbate the above-mentioned dispersion tendencies. These values support the known sodic and poorly drained properties of *Basel* soils.

The deep black *Bell (SEQ)* Vertosols sampled show a slightly acidic to neutral surface pH which increases steadily with depth to become moderately to strongly alkaline (Figure 69). Low EC and chloride values are the norm, however, moderate EC (Figure 70) is occasionally present and corresponds with high ESP percentages (but <0.8 dispersion ratios) and pH (SEQ Sites 115 & 383). Clay percentage is varied, ranging from 21 to 51% in surface soils and from >40 to >70% in upper subsoils (Figure 71). Clay percentage declines steeply (<30%) where *Bell (SEQ)* soils overlie sandy D horizons (LARA Site 9001 & 9006). Clay activity ratios range from 0.6 to >1.0 correlating with an expanding clay type (montmorillonite) as would be expected given *Bell's* basalt heritage and vertic nature. Ca:Mg values (Figure 74) range widely (0.3 to 4.4) reflecting a large variation in the dominant cations adsorbed, however, CEC for *Bell (SEQ)* soils is usually high (Figure 75). Those with very low Ca:Mg (<1) are calcium deficient and have magnesium as their most abundant cation and are more prone to the effects of dispersion at depth.

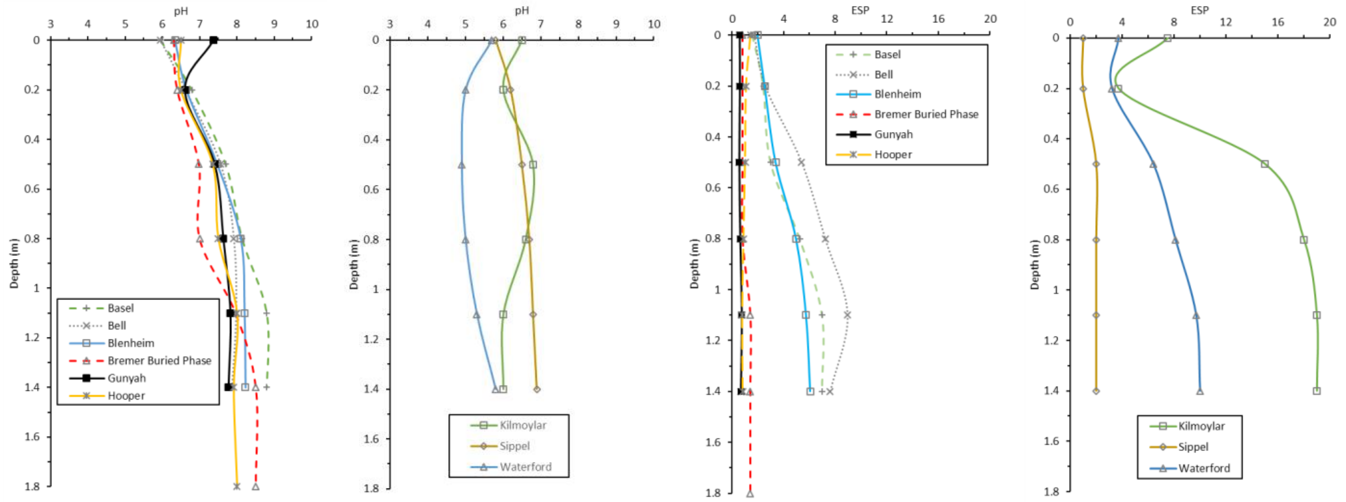


Figure 69. Profile pH and ESP for soils developed on Pleistocene to Holocene alluvial plains

The deep, black cracking clays of the *Blenheim* soils have a slightly acidic to neutral surface (pH 6-7) over a moderately to strongly alkaline subsoil (Figure 69). The whole *Blenheim* profile has low or very low EC's, with the exception of LARA Site 9002 which has a moderately saline (>0.5 dS/m) subsoil below 0.6 m with higher chloride values to match. Clay percentage is high (mostly >40%) throughout (Figure 71) with few exceptions (LARA Site 9012) and high clay activity ratios (all >0.8) suggest that clays will mostly be the expanding montmorillonite type. As would be expected from their clay content, CEC values for *Blenheim* soils (Figure 75) that were tested are very high (>40). However, with few exceptions (LARA Site 9009), Ca:Mg ratios are <2 indicating that magnesium is the dominant cation present. ESP is commonly at non-sodic levels but LARA Site 9002 exhibits moderate sodicity below 0.6 m at depths corresponding to the above-mentioned salinity. However, the corresponding dispersion ratio values are <0.8 suggesting this site might not show physical signs of sodicity.

Both *Bell (SEQ)* and *Blenheim* soils were sampled across multiple locations in various valleys in an attempt to represent the range of soil chemical values that may be found. Individual site results (Table 57) may be more relevant than summary results if working within one of these valleys.

A single, limited horizon sample of the *Bremer Buried Phase* soil was taken from LARA Site 9003 and appears to be broadly similar to the *Bremer* soils tested as part of the BNH survey (Loi *et al*. 2005) in terms of pH, salinity and Ca:Mg ratios. This soil has a slightly acidic to neutral surface underlain by a moderately alkaline buried horizon from 0.32 m. Conductivity (EC) is very low to low, as are chloride values. Clay percentage (14-21%) (Figure 70) is lower than many soils sampled but CEC is ≥35 (Figure 72) and clay activity ratios are very high (>1.5), signifying its potential nutrient holding capacity remains acceptable. Additionally, Ca:Mg ratios of 1.7 to 2.1 suggest that calcium rather than magnesium is dominant on clay surfaces. Levels of available sodium are low resulting in a low ESP.

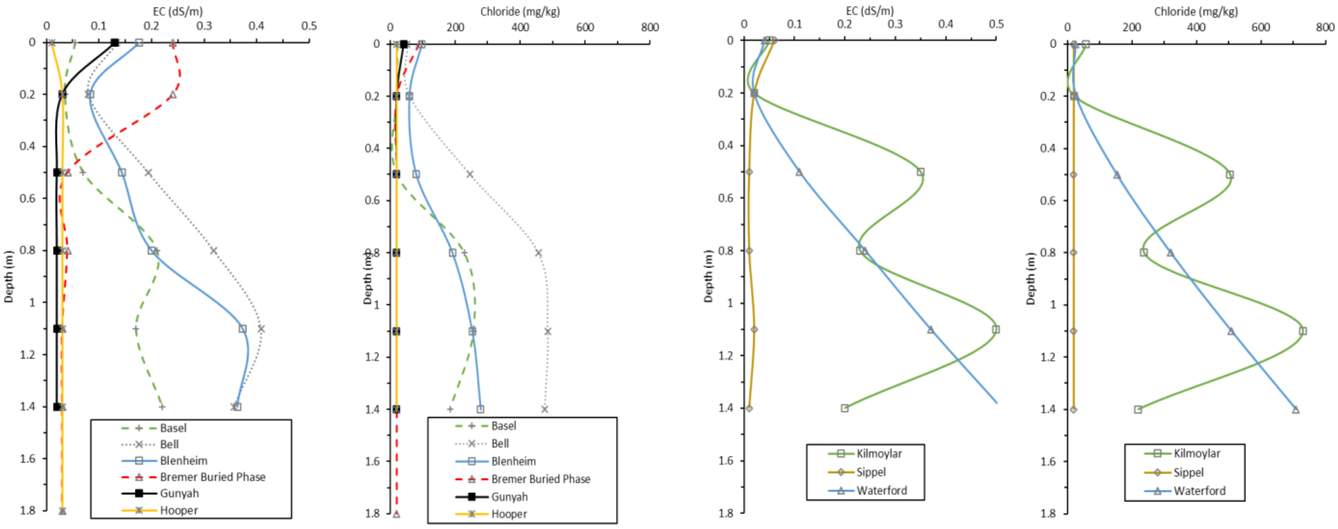


Figure 70. Profile EC and chloride for soils developed on Pleistocene to Holocene alluvial plains

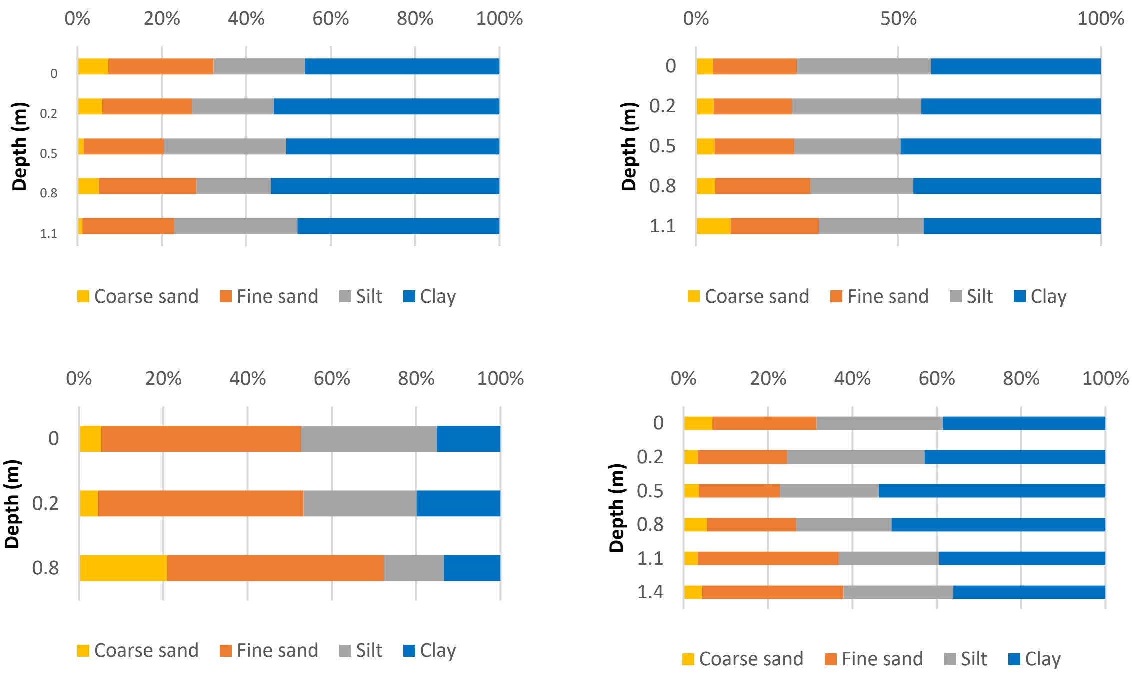


Figure 71. Particle size analysis for *Basel* (top left), *Bell (SEQ)* (top right), *Bremer Buried Phase* (bottom left) and *Blenheim* (bottom right)

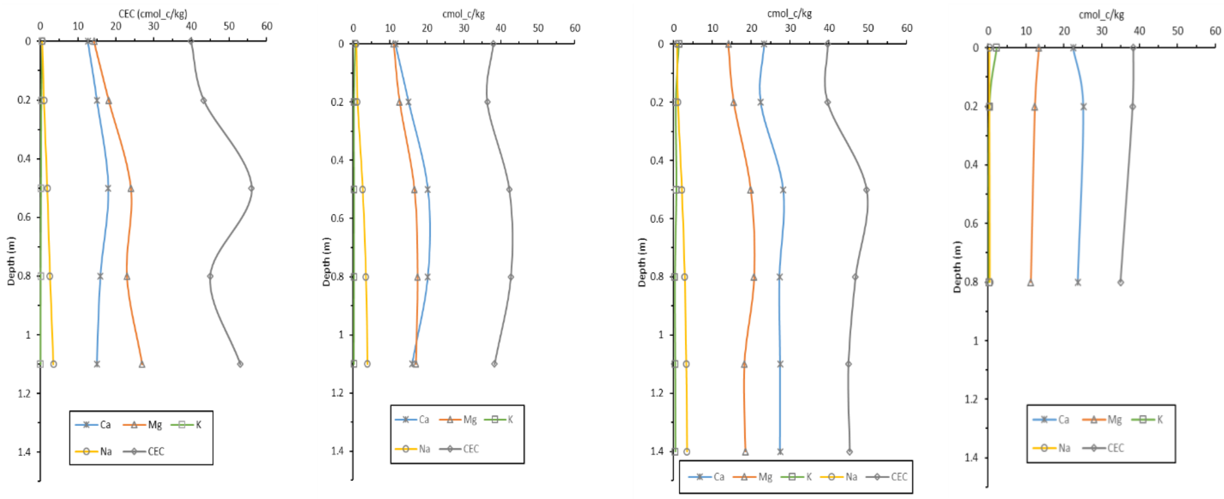


Figure 72. CEC and cations for (left to right) *Basel, Bell (SEQ), Blenheim* and *Bremer Buried Phase*

The pH of the *Gunyah* soil is neutral to mildly alkaline throughout, with EC and chloride very low or low from surface to subsoil. ESP values are extremely low (<1) and dispersion ratios are all <0.7 implying that dispersion is unlikely to occur in this profile. As would be expected from a texture contrast soil, surface clay percentage is low (<15%) (Figure 69) and increases (only slightly) with depth to maximum of 23%. Despite this, CEC maintains levels of 27-37 cmol/kg (Figure 74), possibly due to the presence of montmorillonite clay as indicated by high clay activity ratios (>1.5). The Ca:Mg ratio of 1.9-2.2 indicates calcium rather than magnesium is dominant on clay surfaces.

Hooper soils are represented by a limited horizon sample (LARA Site 9011). The pH varies little down the profile, ranging from slightly acidic (pH 6.5) to moderately alkaline (pH 7.9) while EC is very low or low throughout. ESP and dispersion ratio figures are low and indicate sodicity or dispersion is unlikely. Moderate clay percentages (23-39%) (Figure 73) with high CEC (Figure 74) and clay activity ratios suggest good nutrient and moisture retention potential, though a low Ca:Mg ratio indicates this CEC is currently magnesium dominated.

The *Kilmoylar* soils sampled (LARA Site 9011 & SEQ Site 162) have a moderately acidic to neutral (pH 5.9 to 7.0) soil reaction trend (Figure 68) and an EC that varies from very low (0.01 dS/m) at LARA Site 9011 to moderate (0.36 dS/m) or high (0.91 dS/m) at SEQ Site 162 below 0.3 m (Figure 70). This salinity at SEQ Site 162 corresponds to high ESP figures (>15% - strongly sodic) and dispersion ratios (>0.8) at the same depths (Figure 69). Field testing indicated no dispersion at this site or other *Kilmoylar* sites due to high salinity. The siltstone and sandstone heritage of *Kilmoylar* is the most likely source of the sodium that is dominating its CEC (Figure 74) at this site. The high level of sodium will influence soil properties such as drainage and permeability which both reduce soil suitability, through the wetness limitation, but also alter the balance of other more plant-beneficial nutrients and may prove toxic to sodium sensitive plants e.g. citrus. Ca:Mg ratios also vary greatly (Figure 75). At LARA Site 9011 Ca:Mg ratios are 1.9 to 2.8 which are better balanced than the magnesium heavy Ca:Mg ratios of 0.4 to 1.4 at SEQ Site 162, which, combined with the high sodium concentrations above, would leave little room for more desirable cations and points to a soil of possibly poor nutrition. The texture contrast nature of *Kilmoylar* is evident in the increase of clay content below 0.2-0.3m (Figure 73).

The *Sippel* representative profile has a soil reaction trend that ranges from a medium acid surface to a slightly acid to neutral subsoil and EC values that are very low. ESP and dispersion ratio values are also low in this sample, however, some *Sippel* soils may be moderately sodic or saline. The fact that *Sippel* is a sandstone derived texture contrast soil is reflected in the clay percentages which are 13%

in the surface but increase to 26% in the subsoils (Figure 73) and in the associated, low to moderate, CEC values (Figure 74). Clays are likely to be non-expanding illite (clay activity ratio ≤0.5) and while these results show their adsorption surfaces are expected to be magnesium dominated, Ca:Mg ratios of 2.2 to 3.1 are better than might be expected for these soils, which may assist in countering any possible dispersion. Calculating the amount of exchangeable calcium and magnesium as a percentage of the modest CEC reveals that between 93% and 97% of the CEC is occupied by these two cations, with calcium being dominant.

Waterford soils are strongly or very strongly acidic Vertosols, illustrated by SEQ Site 317. Surface pH is moderately acidic (pH 5.7), but this reduces to be strongly and very strongly acidic (pH 4.9 to 5.3) with depth (Figure 69). Such low pH is likely to reduce the availability of some nutrients and may result in some others becoming toxic (e.g. aluminium, manganese and iron). Additionally, strongly acidic soils restrict exploration by plant roots, reducing nutrient and water uptake. EC values are generally low but rise to moderate below 0.6 m coinciding with mildly sodic ESP at the same depths. The combination of low pH, sodicity and mild salinity means that crop and pasture growth in this soil will not be optimal. As would be expected of a soil with vertic properties, clay percentage is very high (>60 in subsoils) (Figure 73), however, clay activity ratios of 0.3 to 0.5 indicate that clay type is weighted towards the non-expanding illite but some of the expanding montmorillonite type must be present. Low Ca:Mg ratios of 0.8 to 1.1 (Figure 75) again suggest that the cation exchange complex is dominated by magnesium which may exacerbate the above-mentioned sodicity. *Waterford* soils are generally considered unsuited to agriculture.

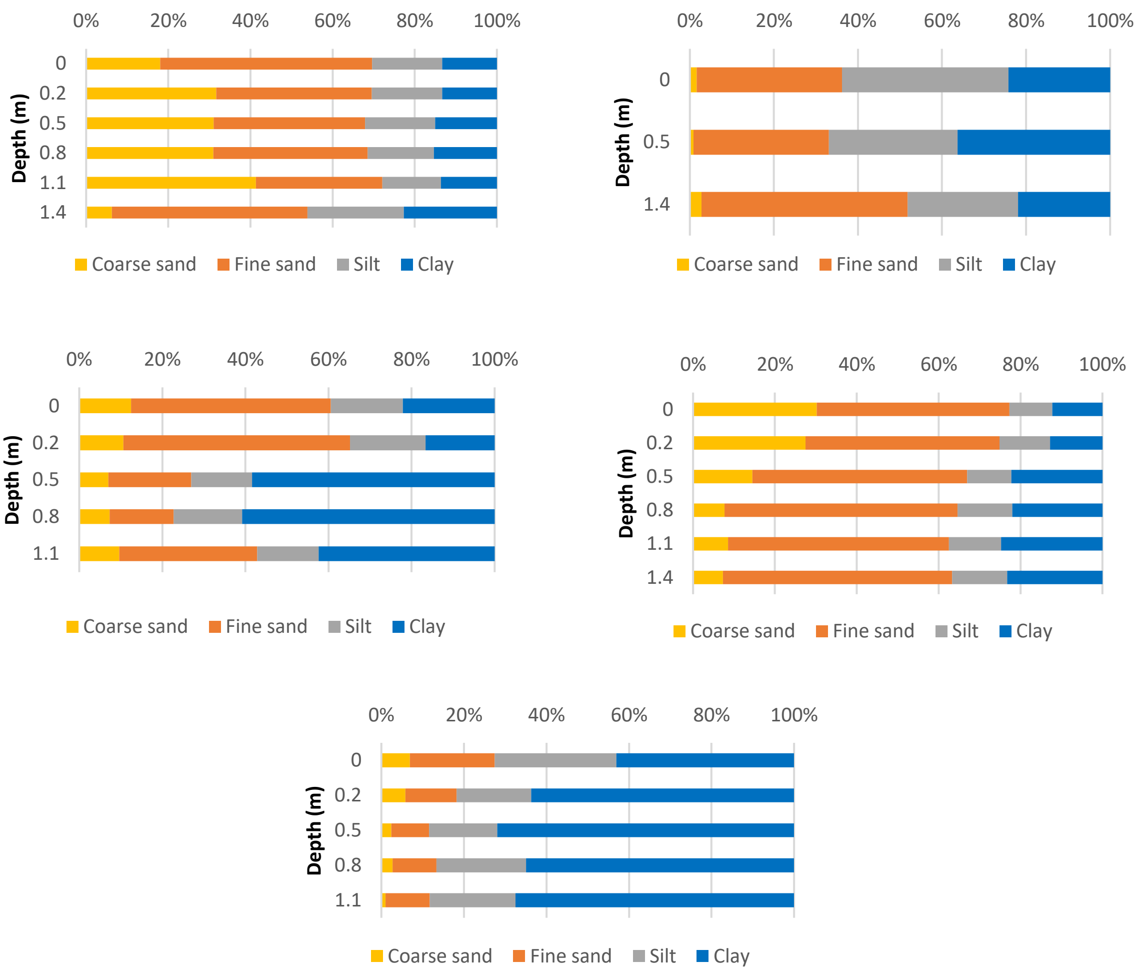


Figure 73. Particle size analysis for *Gunyah* (top left) *Hooper* (top right), *Kilmoylar* (middle left), *Sippel* (middle right) and *Waterford* (bottom row)

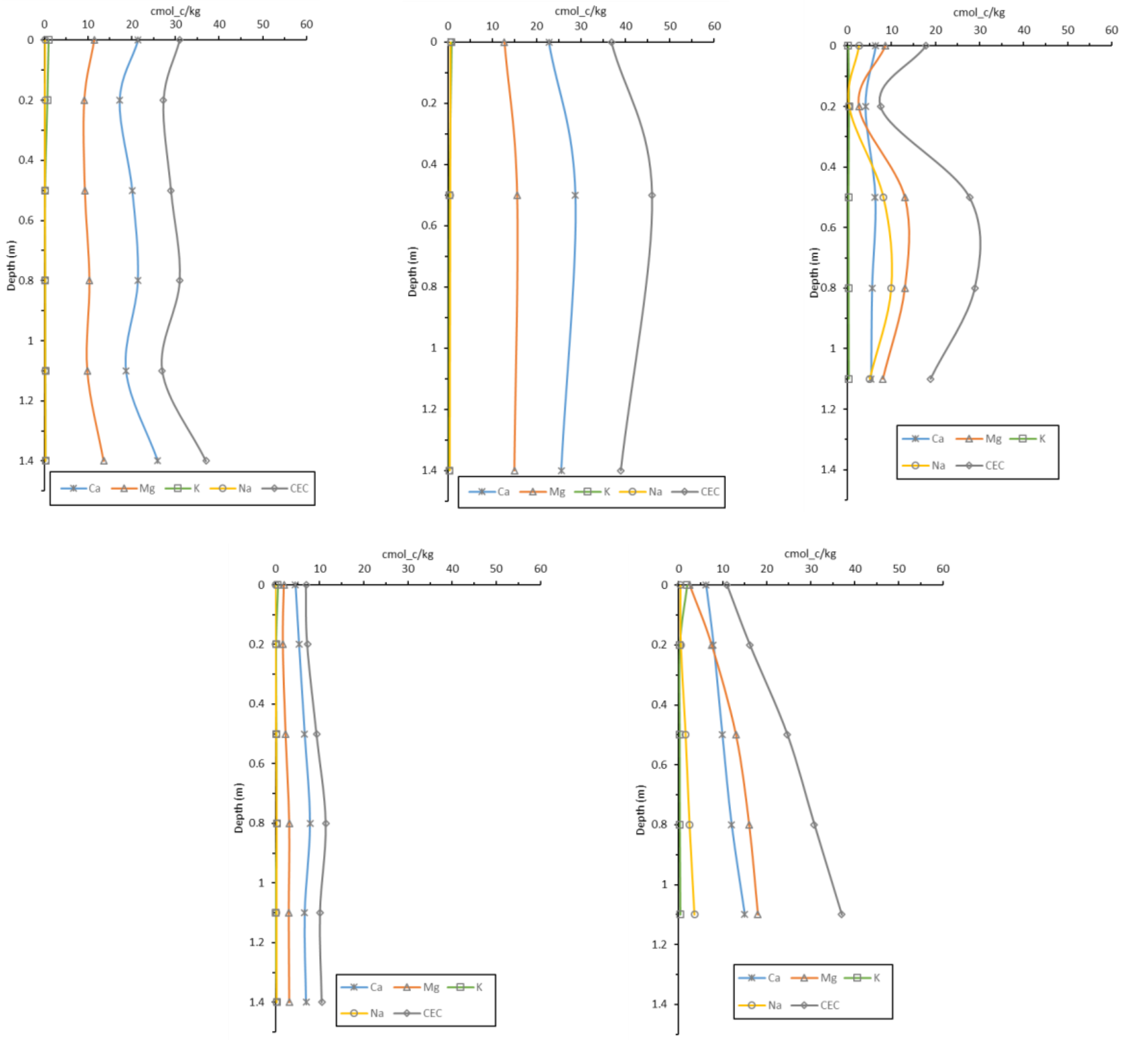


Figure 74. CEC and cations for *Gunyah* (top left), *Hooper* (top centre), *Kilmoylar* (top right), *Sippel* (bottom left) and *Waterford* (bottom right)

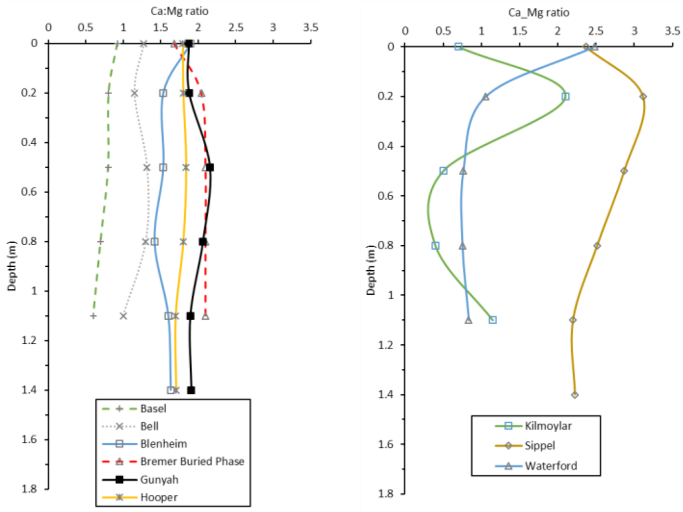


Figure 75. Ca:Mg ratios for soils developed on Pleistocene to Holocene alluvial plains

Other soils developed on Pleistocene and Holocene alluvial plains that have not been discussed above are discussed below. They have been placed into three general groups-soils formed on basalt dominated sediments, soil formed on sandstone and siltstone dominated sediments and soils formed on sediments of mixed origin (Tables 58 to 60).

Other soils formed on basalt dominated Quaternary (Pleistocene to Holocene) alluvium are *Cooeeimbardi* and *Lockrose*.

As these soils are dominated by basalt materials their pH values (Table 58) are expected to be similar to in situ basalt soils. Surface pH ranges from strongly acid (*Lockrose*) through to mildly alkaline (*Cooeeimbardi*). Subsoil pH's are similar, but may reach higher values (>8.5). The occurrence of calcium carbonate nodules and soft segregations is possible in these soils, something which is only observed at high pH. At such high pH many nutrients would begin to become less available for plant growth (e.g. iron, potassium and zinc).

Electrical conductivity is very low or low in surface horizons (<0.25 dS/m), however, subsoil EC is variable. *Cooeeimbardi* and *Lockrose* may have subsoil EC's as high as or higher than 1.0 dS/m. These values (especially in the upper horizons where roots will grow) are unlikely to impact crop or pasture growth and may be related to the movement of salts downward as a result of intense fertiliser use and frequent irrigation.

Sodicity is not a common, or significant, feature of these soils. The clay content of the basalt derived soils is high (as would be expected) and it therefore follows that water holding capacity (PAWC) and likely fertility (depending upon pH) are also high.

These soils (along with *Bell (SEQ)* and *Blenheim*) constitute the majority of the best cropping/pasture soils in the Logan and Albert Rivers catchment and their properties (Table 58) support this.

Table 58. Field-measured properties of soils developed on basalt dominated Quaternary (Pleistocene to Holocene) alluvium

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely Fertility
Cooeeimbardi (Cb)	M-Acid to M-Alk	M-Acid to S-Alk	L	L-H	No	H	High
Lockrose (Ls)	S-Acid to M-Alk	M-Acid to S-Alk	VL-L	L-VH	No	VH	High

Other soils formed on sandstone and siltstone dominated Quaternary (Pleistocene to Holocene) alluvium are *Beausang, Cookes, Maclean, Maroon* and *Spencer*.

Surface acidity in these soils is significantly lower than those derived from basalt, consistently ranging from very strongly acid to slightly acid or neutral. Subsoil acidity is, however, more variable in this group with soils such as *Cookes, Maclean,* and *Maroon* having extremely acidic to strongly acidic subsoils while those of *Beausang* vary from strongly acid to neutral. *Spencer* has subsoils that may be slightly acidic at their upper extents but increase to be strongly to very strongly alkaline at depth. Acidic surface horizons in this group of soils may increase concentrations of undesirable nutrients (manganese, aluminium and iron) and some mild micronutrient deficiencies.

Low or very low EC values (Table 59) are common for the surface of these soils, increasing to very low to medium for the majority of subsoils. Some *Beausang* sites have been found to have high levels of salinity (>1.0 dS/m) that may limit root exploration in some plant species.

Sodicity is common in *Beausang* and *Spencer*. In these soils drainage and permeability will be drastically reduced from the top of the B horizon and this in turn will limit plant root growth and inhibit the cultivation of species sensitive to waterlogging. Additionally, the clay surfaces of these soils may be dominated by sodium, reducing the retention of more desirable nutrients. The observed accumulation of manganese as segregations (commonly nodules) in all but *Maclean* soils is indicative of the pH and impeded drainage conditions that prevail.

PAWC varies greatly from low (*Spencer*) to high (*Cookes, Maclean* and *Maroon*) with *Beausang* rated as moderate. Acidity, drainage and sodicity are the predominate factors working to limit PAWC via limiting the suitable root zone available for roots to explore.

Table 59. Field-measured properties of soils developed on sandstone and siltstone dominated Quaternary (Pleistocene to Holocene) alluvium

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely Fertility
Beausang (Bg)	VS-Acid to N	S-Acid to S-Alk	VL-L	L-H	Yes	M	Mod
Cookes (Co)	S-Acid to M-Acid	VS-Acid to S-Acid	L	L-M	No	H	Low
Maclean (Ma)	S-Acid to M-Acid	E-Acid to S-Acid	L	L-M	No	H	Low
Maroon (Mr)	VS-Acid to N	E-Acid to S-Acid	L	L-M	No	H	Low
Spencer (Sp)	S-Acid to SL-Acid	M-Acid to S-Alk	VL	VL-M	Yes	L	Mod

The above limitations of acidity, sodicity, drainage and variable clay contents are reflected in the likely fertility values for these soils which range from low to moderate only, with the lowest values belonging to those soils with sandier (lower CEC) upper horizons and/or acidic or sodic B horizons (*Cookes, Maclean* and *Maroon*).

Other soils formed on mixed origin Quaternary (Pleistocene to Holocene) alluvium are *Bremer, Bridge, Bromelton, Cressbrook, Duggua, Grigor, Jimboomba, Lockyer, Logan, Monsildale, Payne* and *Robinson*.

As would be expected from a group of soils with mixed parent materials, their properties are varied with few consistent trends (Table 60).

Soil surface pH's from strongly acidic (pH 5.1 to 5.5 – *Bremer, Cressbrook, Duggua, Jimboomba, Payne* and *Robinson*) to moderately alkaline (pH 6.0 to 7.5 – *Lockyer*) were encountered and these values infer a range of possible fertility effects from nutrient toxicity (strongly acidic soils) or scarcity (moderately acidic soils) to wide availability (neutral soils). Subsoil pH's are again variable from a few soils that are extremely and very strongly acidic (*Bridge, Bromelton* and *Payne)* to many which may be strongly alkaline (*Bremer, Duggua, Lockyer* and *Robinson*), however, many of the soils here straddle the moderately acidic to slightly acidic/neutral range (*Cressbrook, Grigor, Jimboomba, Logan* and *Monsildale*). The full range of impacts on nutrient toxicity and availability would be present depending upon pH.

Several soils (*Basel, Bremer, Bridge, Duggua, Grigor, Gunyah, Logan and Payne*) exhibit regular manganese segregations, pointing to lower pH and poor drainage conditions. Calcium is also present in a number of soils (*Duggua, Gunyah and Lockyer*) as insoluble calcium carbonate where calcium is in abundance. In these cases, drainage may be restricted and pH >8.5.

Salinity (EC) of surface horizons is mostly very low or low (<0.25 dS/m), however the surface of Duggua soils are moderately saline (0.25-<0.5 dS/m). These levels are unlikely to present restrictions to the common plant species grown in this catchment. Subsoil salinity is similarly consistent with the majority of soils having a subsoil EC <0.5 dS/m. The exceptions, which may have high to extremely high levels, are *Bromelton*, *Duggua* (also has a higher surface EC) and Lockyer (0.5 to >1.5 dS/m).

Table 60. Field-measured properties of soils developed on mixed origin Quaternary (Pleistocene to Holocene) alluvium

Soil (SPC)	Surface pH	Subsoil pH	Surface EC	Subsoil EC	Disp.	PAWC	Likely Fertility
Bremer (B)	S-Acid to MO-Alk	M-Acid to S-Alk	VL-L	VL-M	No	VH	High
Bridge (Br)	S-Acid to M-Acid	VS-Acid to S-Acid	VL-L	L	No	M	Low
Bromelton (Bn)	M-Acid to M-Alk	E-Acid to S-Acid	VL-L	M-EH	No	M	Low
Cressbrook (Cr)	S-Acid to N	M-Acid to N	L	L	No	L	Poor
Duggua (Du)	S-Acid to N	M-Acid to S-Alk	M	H	Rare	H	Mod
Grigor (Gr)	M-Acid to N	M-Acid to N	VL	L	No	M	Low
Jimboomba (Jm)	S-Acid-SL-Acid	S-Acid to SL-Acid	VL	VL	No	L	Poor
Lockyer (Ly)	M-Acid to MO-Alk	M-Acid to S-Alk	VL-L	VL-VH	No	H	High
Logan (SEQ) (Lg)	M-Acid to M-Alk	SL-Acid to M-Alk	VL-L	L-M	No	M	Mod
Monsildale (Mn)	M-Acid	M-Acid to N	VL	L	No	H	High
Payne (Pn)	S-Acid to SL-Acid	VS-Acid to N	VL-L	VL-L	Yes	M	Low
Robinson (Rs)	S-Acid to N	M-Acid to S-Alk	VL-L	VL-L	No	L	Low

Sodicity is not common in any of these soils apart from *Payne*, which consistently exhibits sodic tendencies. *Payne*, while of mixed alluvium origin, is still predominately sandstone/siltstone derived and this is the likely source of sodium which is inducing the sodicity.

PAWC varies from low in sandy soils (*Cressbrook, Jimboomba* and *Robinson*) to moderate (*Bridge, Bromelton, Grigor, Logan* or *Payne*) in texture contrast soils or soils with B horizon limitations (e.g. sodicity, poor drainage, high acidity) to high or very high in high clay percentage soils with few or no root zone limitations (*Bremer, Lockyer* and *Monsildale*).

The likely fertility incorporates the above characteristics and it follows that those soils with high PAWC, low salinity/sodicity and moderate acidity to moderate alkalinity (*Bremer, Lockyer* and *Monsildale*) rate highest (moderate to high). Conversely those with low PAWC and high acidity/sodicity/salinity rank lowest (*Bridge, Bromelton, Cressbrook, Payne* and *Robinson*).

10.11 Soil surface fertility

Results for surface fertility are available for 16 of the sampled profiles within the study area, covering 10 SPC's on Pleistocene to Holocene alluvial plains, the Neogene basalts and Triassic to Jurassic sediments. All of these SPC's are commonly used for agricultural production of one form or another.

10.11.1 Soils of the Quaternary (Pleistocene to Holocene) alluvial plains

The alluvial soil surfaces sampled show that the analytes are present in adequate concentrations for plant growth, with only minor and inconsistent deficiencies (Table 61).

The basalt derived soils (*Bell (SEQ)* and *Blenheim*) exhibit some low values of sulphur (LARA Site 9012 and SEQ Site 95) or potassium (LARA Site 9001) while all other nutrients are considered adequate and will likely be supplemented, as required, when planting crops or renovating pastures. This is expected for the basalt derived (and most fertile soils) in this area. Consistently high values of P and K for *Blenheim* soils is linked to their cropping land use and the possible over use of fertilisers.

Table 61. Surface fertility of soils on alluvial plains

Depth (m)	pH 1:5 water	EC (dS/m)	Cl (mg/kg)	Org. C (%)	Tot. N (%)	P (mg/kg)	K (mg/kg)	S (mg/kg)	DTPA extractable elements (mg/kg)			
									Cu	Zn	Fe	Mn
Basel (SEQ Site 402)												
0-0.1	5.9	0.13	54	2.90	0.22	198	352	17	1.7	3.8	175	25
Bell (SEQ) (LARA Site 9001)												
0-0.1	5.9	0.19	225	1.35	0.14	64	58.7	17	1.1	4.5	110	48
Bell (SEQ) (SEQ Site 95)												
0-0.1	6.4	0.07	30	2.40	0.14	160	430	5	1.0	3.4	111	19
Bell (SEQ) **(**SEQ Site 115)												
0-0.1	5.6	0.10	46	2.30	0.16	28	391	24	1.6	1.9	94	61
Bell (SEQ) (SEQ Site 383)												
0-0.1	5.8	0.13	75	7.70	0.55	196	313	16	4.0	19	453	66
Bell (SEQ) (SEQ Site 393)												
0-0.1	6.0	0.15	86	5.30	0.39	358	313	32	1.9	2.5	347	16
Blenheim (LARA Site 9002)												
0-0.1	6.25	0.07	24	2.90	0.26	193	508	11	6.3	2.6	291	25
Blenheim (LARA Site 9009)												
0-0.1	6.42	0.11	<20	2.74	0.28	148	117	29	2.7	4.7	158	26
Blenheim (LARA Site 9012)												
0-0.1	6.33	0.08	<20	2.50	0.29	770	469	6	1.9	4.0	140	18
Gunyah (LARA Site 9005)												
0-0.1	7.1	0.07	<20	1.42	0.12	81	469	10	1.0	1.4	70	9.7
Kilmoylar (SEQ Site 162)												
0-0.1	5.7	0.05	20	3.10	0.20	40	235	11	0.9	5.4	182	42
Sippel (SPFD 108)												
0-0.1	6.0	0.03	21	1.50	0.08	7	196	4	0.7	3.6	110	19
Waterford (SEQ Site 317)												
0-0.1	5.5	0.16	78	3.00	0.23	32	352	26	1.8	2.1	175	114

See individual sites in Appendix 3 for laboratory methods used.

Organic matter (OM), as measured by organic carbon (OC), varies across *Bell (SEQ)* sites and is strongly linked to land use. SEQ sites 383 and 393 represent grazing land uses while LARA 9001 is a site that has been repeatedly cultivated for dairy fodder where plant material is removed and fed elsewhere. Cultivation is known to expose and oxidise OM and accelerate its breakdown, while grazing results in less soil exposure and accumulation of OM through deposited plant and soil fauna material and animal manures. The *Blenheim* soils analysed show a more consistent level of OC (2.5-2.9%) and while they are also cropped for animal feed (mostly ryegrass and sorghum for dairy cattle) the crop is grazed in situ, not removed and fed elsewhere. This allows some added balance between OM removal and replacement via plant residue accumulation and manure deposition. Both *Gunyah* and *Waterford* samples analysed have acceptable levels of OC (≥3%), however, the OC of the *Sippel* sample is considered low at 1.5%. *Sippel* is a texture contrast soil with a sandy loam surface and it was cropped at the time of sampling.

Of the sandstone and siltstone derived soils *Sippel* showed low levels of phosphorus, total nitrogen and sulphur while the *Waterford* sample had a slightly low level of phosphorus. This is reflective of a soil derived from a parent material with poorer nutrient content. These soils are mostly used for grazing or other low nutrient demand purposes less likely to be impacted by these results.

In all results manganese levels are considered high or very high and may lead to toxicity, but this will be plant species dependant. Salinity (EC and chloride concentration) of all samples is not of concern.

10.11.2 Soils developed on Neogene volcanics (basalts)

The *Glenapp* soil sampled here represents many soils on lower slopes and fans of the Miocene basalts used for cropping and intensive (irrigated) fodder production. Fertility levels of the surface soils (Table 62) are suitable for these purposes and are likely to be supplemented to ensure adequate yields. This *Glenapp* soil has a very high level of potassium that may result from its recent dairy fodder cropping use and associated fertiliser application. Manganese is present at a very high, and potentially mildly toxic level, but this is plant species dependant. Chloride is present at only very low concentration and is not of concern.

Table 62. Surface fertility of soils developed on Neogene volcanics

Depth (m)	pH 1:5 water	EC (dS/m)	Cl (mg/kg)	Org. C (%)	Tot. N (%)	P (mg/kg)	K (mg/kg)	S (mg/kg)	DTPA extractable elements (mg/kg)			
									Cu	Zn	Fe	Mn
Glenapp (LARA Site 9007)												
0-0.1	6.58	0.07	<20	3.19	0.33	113	508	8.4	2.1	2.4	141	31

10.11.3 Soils developed on Triassic to Jurassic sediments

This *Gould* sample had a mostly sufficient level of nutrients at the surface, however, the level of total nitrogen is only moderate and potassium is considered marginal (Table 63). Both could need to be supplemented dependent upon land use. The *Koukandowie* sample also exhibits low total nitrogen accompanied by a marginal level of sulphur, again these are sufficient for native pastures but may require supplementing if greater production is needed. As was the case with the samples above, chloride levels are below concern. Both samples have high organic carbon levels that possibly reflect the long term pasture history at the sites sampled. High concentrations of iron and manganese may have toxic effect on some plant species.

Table 63. Surface fertility of soils developed on Triassic to Jurassic sediments

Depth (m)	pH 1:5 water	EC (dS/m)	Cl (mg/kg)	Org. C (%)	Tot. N (%)	P (mg/kg)	K (mg/kg)	S (mg/kg)	DTPA extractable elements (mg/kg)			
									Cu	Zn	Fe	Mn
Gould (MFM Site 425)												
0-0.1	5.6	0.07	28	2.70	0.20	36	117	-	1.7	3.7	203	143
Koukandowie (SEQ Site 152)												
0-0.1	5.5	0.12	62	4.40	0.29	238	469	12	0.8	26	335	99

10.12. Soil water availability

Soils suitable for agricultural uses require the ability to retain moisture for use by plants, this is known as soil water availability and this is measured by plant available water capacity (PAWC). PAWC has been calculated, in this instance, using the plant available water capacity estimation routine (PAWCER) (Littleboy & Glanville 1995) to a depth of 1.0m unless limited by chemical (pH, EC/chloride or sodicity) factors.

PAWCER requires the input of laboratory supplied particle size analysis (percentage of clay, silt and sand) and the lower limit of available soil water content, as measured by the minus 15 bar suction test. Results are presented in Table 64 and Figure 76 for the SPC's where appropriate data is available, alongside PAWC data estimated using soil moisture look-up tables (Department of Natural Resources and Mines and Department of Science Information Technology, Innovation and the Arts 2013). Figure 76 further demonstrates the variation in PAWCER calculated PAWC across soils and depths.

Soil water availability is used to inform the land suitability classification scheme (Appendix 4).

Table 64. PAWC values for SPC's with data available

SPC (number of sites used for PAWCER)	Geological group	PAWCER PAWC (mm/m)	Look-up table PAWC (mm/m)
Basel (1)	Alluvium	115	108 (Range 90-120)
Bell (SEQ) (5)	Alluvium	118 (Range 87-137)	100 (Range 80-120)
Blenheim (3)	Alluvium	117 (Range 98-120)	115 (Range 105-120)
Glenapp (1)	Basalt	116	120 (Range 115-125)
Gould (1)	Siltstone/sandstone	59 (chloride limited)	95 (Range 90-100)
Gunyah (1)	Alluvium	66	85 (Range 65-110)
Kilmoylar (1)	Alluvium	48 (chloride limited)	85 (Range 65-105)
Koukandowie (1)	Siltstone/sandstone	77 (chloride limited)	30 (Range 15-50)
Sippel (1)	Alluvium	72	75 (Range 50-110)
Tamborine (1)	Basalt	124 (low pH limited)	95 (Range 65-125)
Waterford (1)	Alluvium	19 (low pH limited)	75 (Range 50-105)

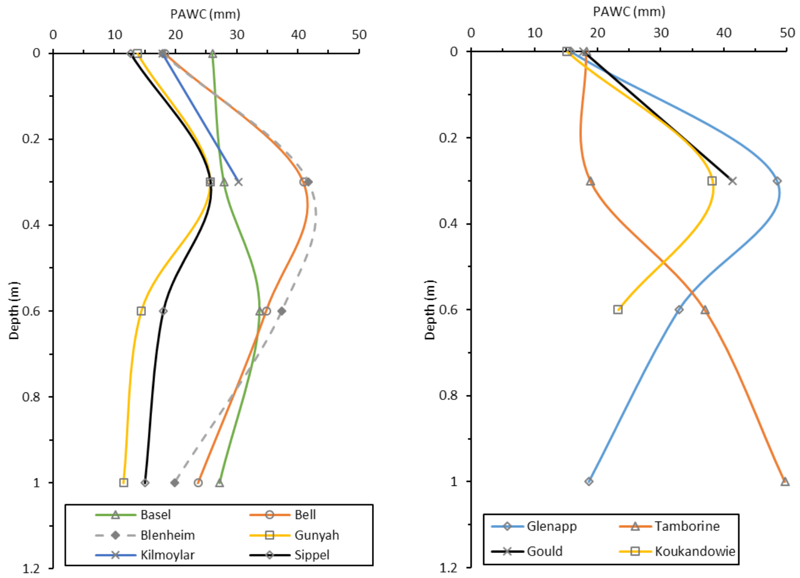


Figure 76. PAWC for some soils developed on Quaternary (Pleistocene to Holocene) alluvial plains

10.13. Additional soil chemical analysis

Further to this project the Queensland Department of Environment and Science are undertaking a specific erosion study considering the impact of eroded sediment on waterways and water storages. Included in their study is the laboratory analysis of many of the sites described (but not sampled) as part of this project. Readers seeking additional laboratory analysis results covering a wider range of soils are encouraged to consult their forthcoming publication.

11. Land degradation

Land degradation is generally described as the decline in land condition resulting from human use. It often begins when the land is disturbed from its natural state (cleared) and developed in the absence of any (or ineffective) conservation measures. Types of degradation such as erosion (often exacerbated by natural sodicity), salinity and invasive weeds are more obvious and can be directly linked to land disturbance and land management.

Other processes which may also result in land degradation include soil compaction, sedimentation, nutrient runoff and waterlogging. However, these later aspects of land degradation are not included in this technical report.

11.1. Erosion

Overall the most prominent forms of soil erosion in the Logan and Albert Rivers catchment are stream bank (Figure 77) and surface sheet erosion (Figure 78), with gully erosion less common (Figure 79). Hancock & Caitcheon (2010) found that stream bank erosion in both the Logan and Albert Rivers was the major erosion mechanism accounting for greater than 50% of sediments, followed by surface soil erosion at greater than 20%, a combined total of over 70%. The same study indicated that another significant source was shallow subsoil erosion resulting from scalding (potentially linked to surface salinity) and cultivation.

Basalts (Albert, Hobwee and Beechmont Basalts) make up the largest proportion (approximately 70%) of the overall sediment contributed to these river systems due to their abundance, topography and exposure to intense rainfall (Resilient Rivers Initiative 2017). However, other geologies also make significant contributions. For instance, the Triassic-Jurassic sedimentary formations (Woogaroo Subgroup, Gatton Sandstone, Koukandowie Formation and Walloon Coal Measures) also erode at substantial rates. Soils on these geologies have been estimated to show major to severe sheet and gully erosion over 30 to 50% of their area (Resilient Rivers Initiative 2017).

The same report also commented that there is severe erosion across 25% of the upper reaches of the Widgee sub-catchment, including a high density and intensity of land slips associated with broad hectare erosion. Gully erosion is significant in areas of the Albert Right sub-catchment, along with relatively high intensity land slips (Resilient Rivers Initiative 2017).

On-site and-off site consequences associated with increased soil erosion range from a decline in soil depth, soil structure, water and nutrient holding capacity of the soil, agricultural productivity and soil health to the destabilisation of infrastructure, reduced water quality and degradation of habitat. There can be significant losses of agricultural land after streambank mass movement.

Silted up waterways with reduced capacity to transmit water flows often have more frequent overbank flooding with eroded soil deposited in road culverts, reservoirs, creeks, rivers and marine environments (Carey *et al*. 2015, Department of Environment and Resource Management 2011). Additionally, nutrients from applied fertilisers, particularly nitrogen and phosphorus, and pesticides that are adsorbed onto eroded clay and silt colloids are readily transported into waterways.

The maintenance of groundcover in all land management scenarios, including agricultural (both cropping and grazing), is critical to reducing or rehabilitating all forms of soil erosion.

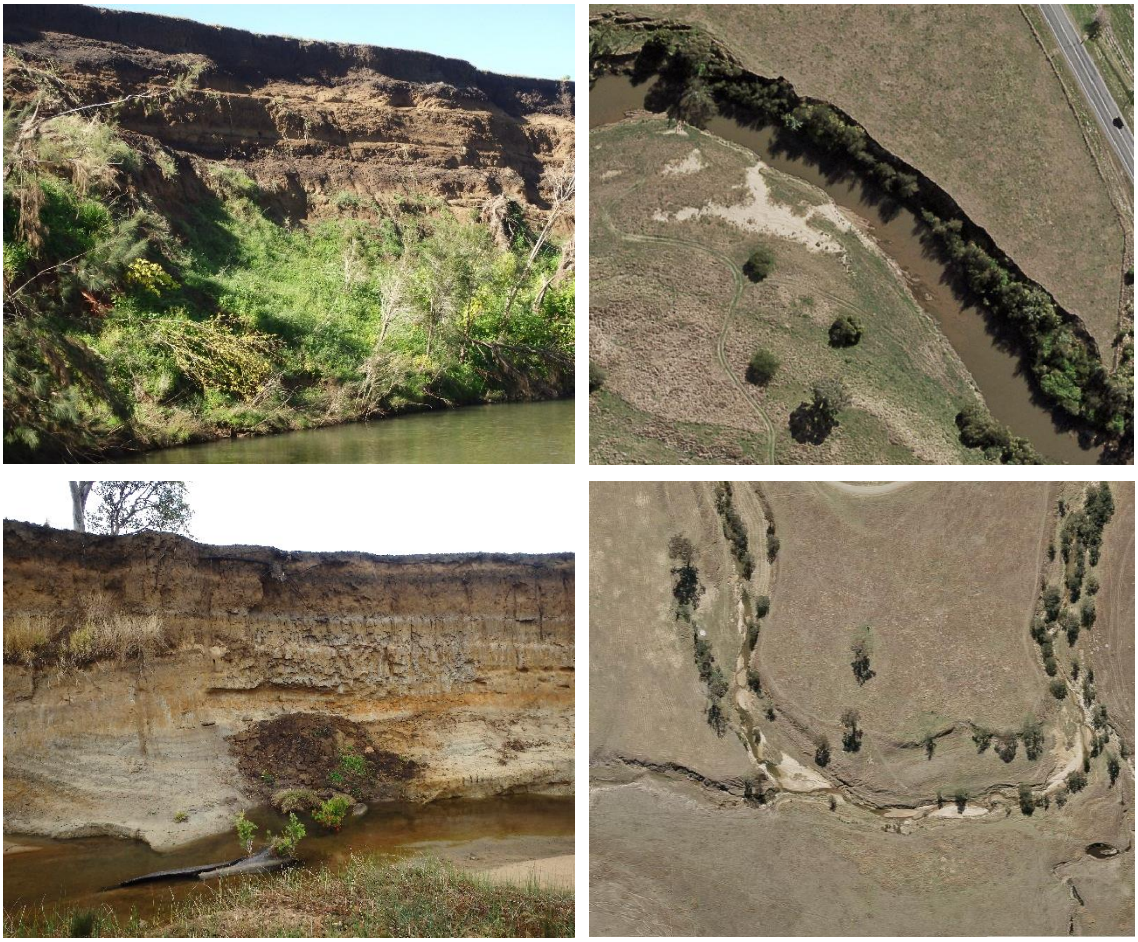


Figure 77. Streambank erosion examples. Top row: eroded stream bank in *Lockrose* soils on the Logan River at Bromelton (note edge of paddock eroding in image on right); Bottom row: stream bank erosion in *Logan* soils on Knapps Creek (note stream widening and joining with adjacent gully erosion on left of the right hand image).

Figure 78. Surface and subsurface erosion in *Kooralbyn* soils on Woogaroo subgroup. Allen Creek (left) and surface (sheet) erosion in *Sarabah* soils on Basalt at Darlington (right).

Figure 79. Sheet and gully erosion examples. Combined sheet and gully erosion occurring in a complex of sedimentary derived sodic *Koukandowie* and *Lowood* soils at Knapp Creek (left) likely the result of cattle movements (tracks); Partially stabilised gully erosion in basaltic *Palen* soils adjacent to Kerry Creek at Nindooinbah (right).

11.2. Salinity

Types and distribution of salinity in the study area largely agree with the findings of a previous report on salinity in the upper parts of the Logan and Albert River catchment (Land Resource Assessment and Management Pty. Ltd. 2007) in that occurrences of secondary salinity are limited and confined to poorly drained areas surrounding Flanagan's Reserve in the upper Logan River. A particularly large salt scald, complete with halophytes, was observed on *Beausang* soils at Site 2008 (Figure 80) with a surface electrical conductivity of 24.8 dS/m.

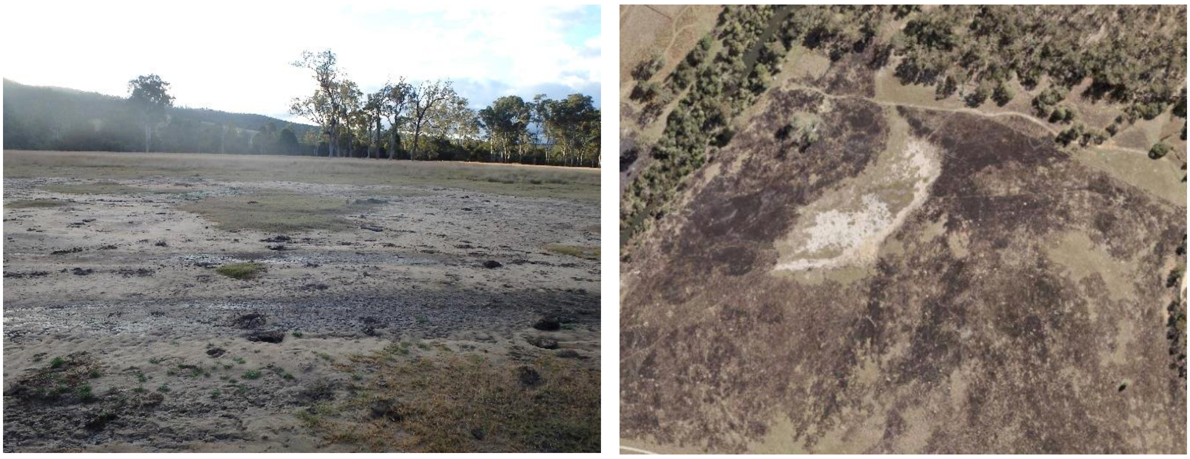


Figure 80. Salt scald/seepage area near Flanagan's Reserve on *Beausang* soils (Site 2008). June 2015 (left) and the same area shown from the air (right).

These areas near the Logan River upstream of Flanagan's Reserve are where sediments from Walloon Coal Measures have been intruded and overlain by later volcanic materials such as rhyolite and basalt which may serve as recharge areas supplying water for catena and alluvial forms of salting (SalCon 1997), aided by poor hydraulic conductivity of adjacent alluvium (Figure 81). Also common to this location are thin coal seams observed within 1.5 m of the current land surface (Sites 322, 336 & 338). It is plausible that natural salinity associated with these coal seams is the primary source of the observed salinity. Electrical conductivity values in these areas range from 0.9 to 14.4 dS/m.

Figure 81. Secondary salinity expression and associated gully erosion in narrow drainage lines in Walloon Coal Measures east of the Logan River and Flanagan's Reserve (near Site 319)

In contrast, areas where the geology is volcanically dominated (primarily the eastern portions of the study area) groundwater flows are not saline and no surface expressions of salting were noted. Sub-surface flows in these areas accumulate beneath adjacent alluvium and are important, localised sources of irrigation water for crops and pastures.

Some slight to mild salinity was noted at depth (>1.5 m) in long term irrigation sites of past and present dairy farms on Logan River alluviums dominated by basalt clays. This is possibly due to intensive animal husbandry leading to an accumulation of salts from both manure and sustained fertiliser use.

11.3. Invasive weeds

Invasive weeds have significant economic, environmental and social impacts. Weeds also increase the risk of fire and costs to infrastructure maintenance, and make recreation areas less pleasant (Business Queensland 2019). They have the potential to:

- damage ecosystems
- reduce productivity and profitability by competing with crop and pasture species for water, nutrients and space
- poison stock
- seriously limit the long-term sustainability of Queensland's agricultural and natural resources
- affect human health.

The following weeds were identified during the field work phase of this project. They fall into three categories – Restricted Invasive Plant, Other Invasive Plant or Other (non-restricted).

11.3.1. Restricted invasive plants:

Fireweed - *Senecio madagascariensis*

Fireweed (Figure 82) is found along the entire New South Wales coast and scattered across various regions of Queensland. Light infestations can produce 1 million seeds per hectare. It occurs in beef and dairy pasture east of Great Dividing Range where it competes with pasture and is toxic to livestock. It is spread by wind, stock, in pasture seed, hay, turf, mulch and with stock transport (Business Queensland 2019). The majority of grazing areas within this project extent contained significant infestations of fireweed.

Giant Rat's Tail Grass - *Sporobolus pyramidalis, S. natalensis*

Found from Cooktown in Queensland to the New South Wales central coast, it grows in a wide range of soils and conditions. It can produce up to 85 000 seeds per square metre in a year, with initial seed viability of about 90%. A significant portion of seed can remain viable for up to 10 years. Giant rat's tail grass (Figure 82) quickly dominates pastures, particularly after overgrazing or soil disturbance, causing losses in carrying capacity and decreases in production of up to 80%. Seeds are spread by livestock in manure, on fur and on hooves, but can also be spread by feral and native animals, vehicles and machinery (especially slashers and earthmoving equipment), in hay and untested pasture seed, and by fast-flowing water over turf (Business Queensland 2019).

Figure 82. Fireweed and Giant Rat's Tail Grass. Left: Fireweed (*Senecio madagascariensis*) at Tabragalba (Site 2116); Right: Giant Rat's Tail Grass (*Sporobolus pyramidalis*) at Running Creek (Site 446)

Lantana - *Lantana camara*

Infestations are located from north Queensland to southern New South Wales. It grows in wide variety of habitats, from exposed dry hillsides to wet, heavily shaded gullies. Lantana (Figure 83) is a heavily branched shrub growing in dense clumps, thickets or vines that smother native vegetation and are impenetrable to animals, people and vehicles. Some varieties are poisonous to stock. It is spread mostly by people and fruit-eating birds (Department of Agriculture and Fisheries, 2016).

Figure 83. Thick lantana (*Lantana camara*) undergrowth on basalt at Lamington Falls (Site 682).

Mother of millions - *Bryophyllum delagoense (syn. B. tubiflorum and Kalanchoe delagoensis), B. x houghtonii (syn. B. daigremontianum x B. delagoense, K. x houghtonii)*

Mother of millions (Figure 84) are popular garden plants which have escaped cultivation and spread to grasslands, woodlands and open dunes in many parts of Queensland including the Central Highlands, Burnett, Moreton and Darling Downs regions. It establishes well in leaf litter or other debris on shallow soils in shady woodlands and is found on roadsides, fence lines, coastal dunes and around old rubbish dumps. Adaptable to dry conditions and poisonous to stock, it is spread by floodwater and establishes if pastures are in poor condition. It is also spread by animals, slashers, machinery and vehicles (Department of Agriculture and Fisheries, 2016).

Figure 84. Mother of-millions (*Bryophyllum* spp.) (North west weeds 2019)

11.3.2. Other invasive plants

Castor Oil Plant - *Ricinus communis*

Castor oil plant is found in all states and territories except Tasmania but prefers warm and subtropical regions. It is often abundant along gullies, watercourses and roadsides, and on floodplains and disturbed land. It can spread quickly, overtaking prime grazing land and making it unfit for livestock (Business Queensland 2019).

11.3.3. Other weeds

These weeds are not restricted or notifiable weeds but they are prevalent and impact crop/pasture productivity in the study area:

- Scotch or spear thistle (*Cirsium vulgare*) (Figure 85)
- Mexican or prickly poppy (*Argemone ochroleuca*) (Figure 85)
- Thorn apples (*Datura spp. Datura stramonium, Datura inoxia*)
- Balloon cotton bush (*Gomphocarpus physocarpus*)

Figure 85. Scotch thistle (*Cirsium vulgare*) and Mexican poppy (*Argemone ochroleuca*) on cultivated alluvial flats (*Bell (SEQ)* soils) at Hillview (Site 2043).

12. Land evaluation

The *Guidelines for agricultural land evaluation in Queensland—2nd Edition* (Department of Science, Information Technology and Innovation & Department of Natural Resources and Mines 2015) provide the framework and procedures for the determination of agricultural land suitability in Queensland. A land suitability assessment considers a series of alternative agricultural uses and identifies land management requirements for sustainable use. The land suitability information produced in this project does not give preference to a particular agricultural use of the land. However, it can be used to determine if the land is generally suitable for sustainable agricultural production.

The *Regional Land Suitability Frameworks for Queensland* (Department of Natural Resources and Mines & Department of Science, Information Technology, Innovation and the Arts 2013) document provides the criteria for assessing suitable crops for individual areas of land within a particular region. This project falls within the area covered by the *Inland SEQ* framework area. This *Inland SEQ* framework has been slightly modified and updated for this project to tailor it to better reflect the characteristics of the Logan and Albert Rivers catchment area and to align it with contemporary land resource publications.

Using this modified suitability framework, the soil and land attributes have been evaluated based on a series of specified land use requirements, incorporating current technology and management practices. Socio-economic factors were considered in general terms only, and water is considered to be available, unless otherwise specified. Irrigation is based on spray or drip irrigation only. Land suitability classes do not equate to actual crop yields or costs. Refer to the *Guidelines for agricultural land evaluation in Queensland—2nd Edition* (Department of Science, Information Technology and Innovation & Department of Natural Resources and Mines 2015) for further explanation. This suitability framework and its components are included in Appendix 4.

Land resource information collected during the project was used to determine crop suitability for the 38 land uses listed in the land suitability framework. The 14 land use limitations (Table 65) were applied across the 1485 UMAs in the project area according to the *Guidelines for agricultural land evaluation in Queensland—2nd Edition* (Department of Science, Information Technology and Innovation & Department of Natural Resources and Mines 2015) Spatial distribution of some of the most common limitations are given in Figures 86-89.

The overall land use suitability for a UMA is, in most cases, determined by its most severe limitation. The severity of each limitation was assigned on a scale of 1 (least limiting) to 5 (most limiting) as follows:

- Class 1 Suitable land with negligible limitations
- Class 2 Suitable land with minor limitations
- Class 3 Suitable land with moderate limitations
- Class 4 Unsuitable land with severe limitations
- Class 5 Unsuitable land with extreme limitations.

A full definition of each of the suitability classes is provided in Appendix 5. Land suitability maps for maize, lucerne, citrus and kikuyu are provided in Figures 90-93. Additional land suitability maps are included in Appendix 6.

Table 65. Land use limitations applied in LARA project

Climate (C) – frost and precipitation (using long term data from Bureau of Meteorology)
Water erosion risk (E)
Flooding (F)
Water availability (M) (plant available water capacity - soil water storage)
Nutrient deficiency (Nd) (derived from laboratory analysis)
Element toxicity (Nt) (pH)
Soil depth (Pd) (based on site data)
Soil surface condition (Ps) (based on site data)
Rockiness (R) (maximum profile coarse fragments)
Soil salinity (Sa) (based on site data)
Microrelief (Tm) (based on site data)
Slope (Ts) (based on safe use of agricultural machinery)
Profile wetness (W1, W2, W3) (combination of drainage and permeability)
Landscape complexity (X) (based on UMA area, topography and location)

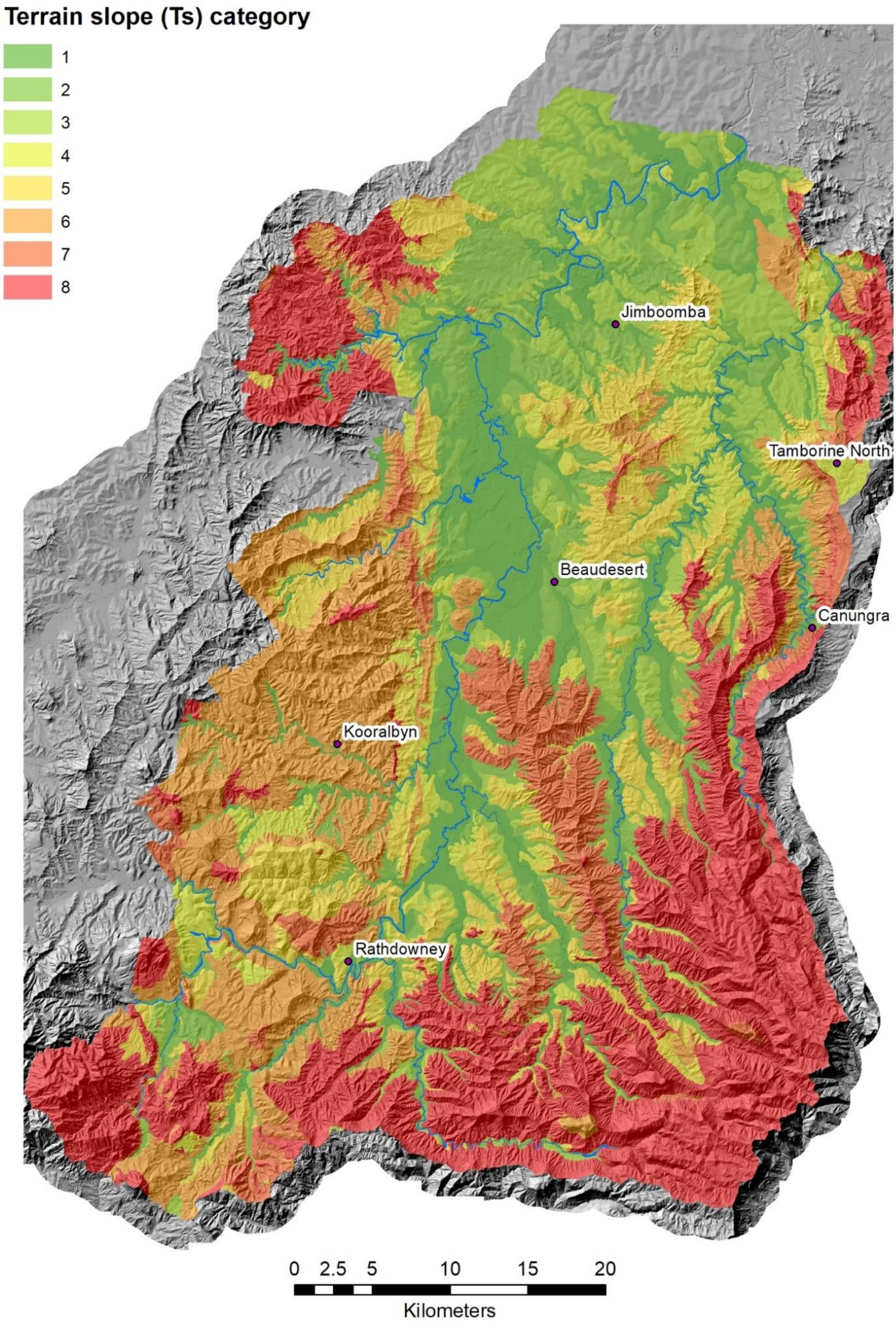


Figure 86. LARA terrain slope (Ts) limitation categories.

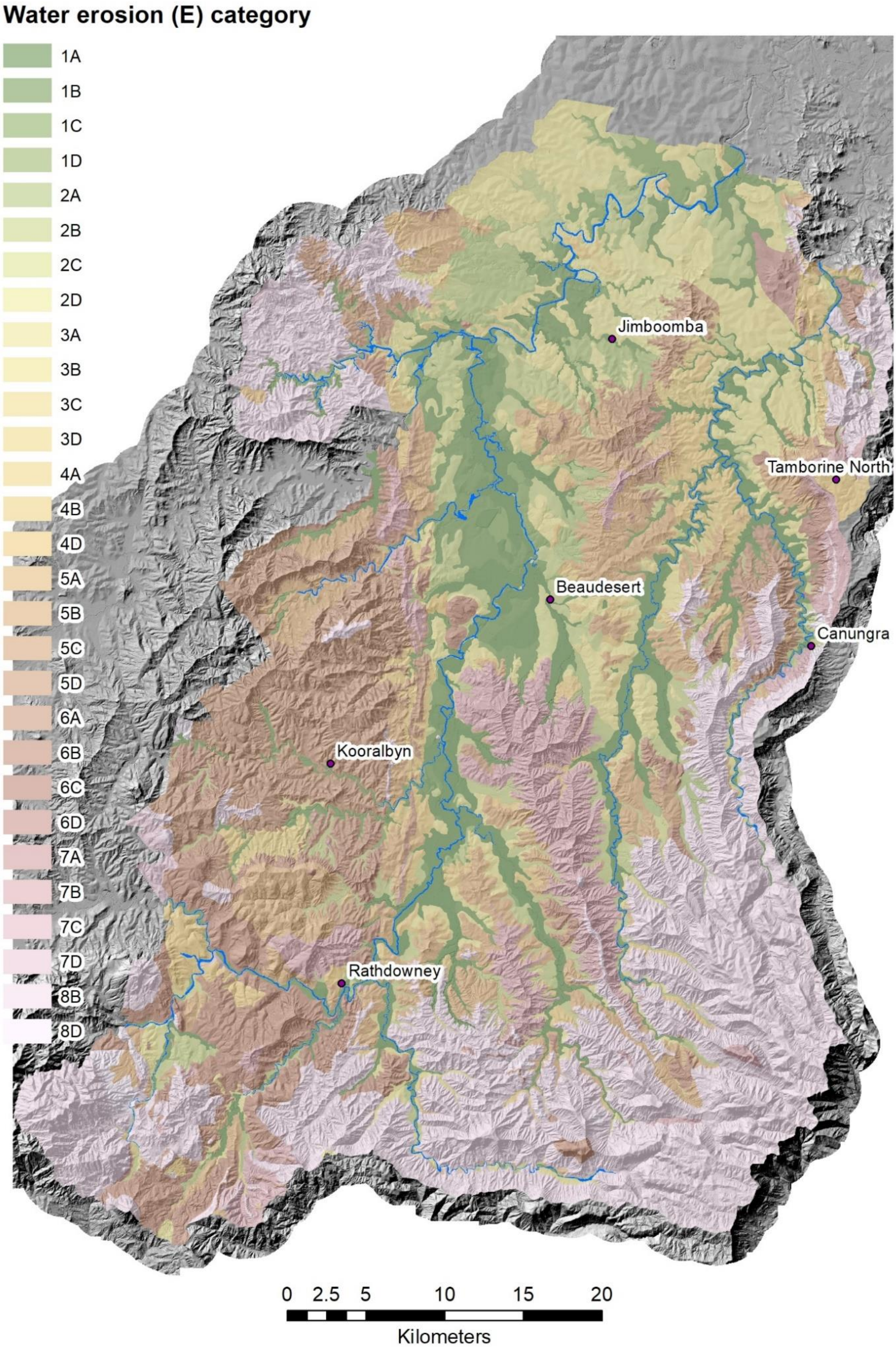


Figure 87. LARA water erosion (E) limitation categories.

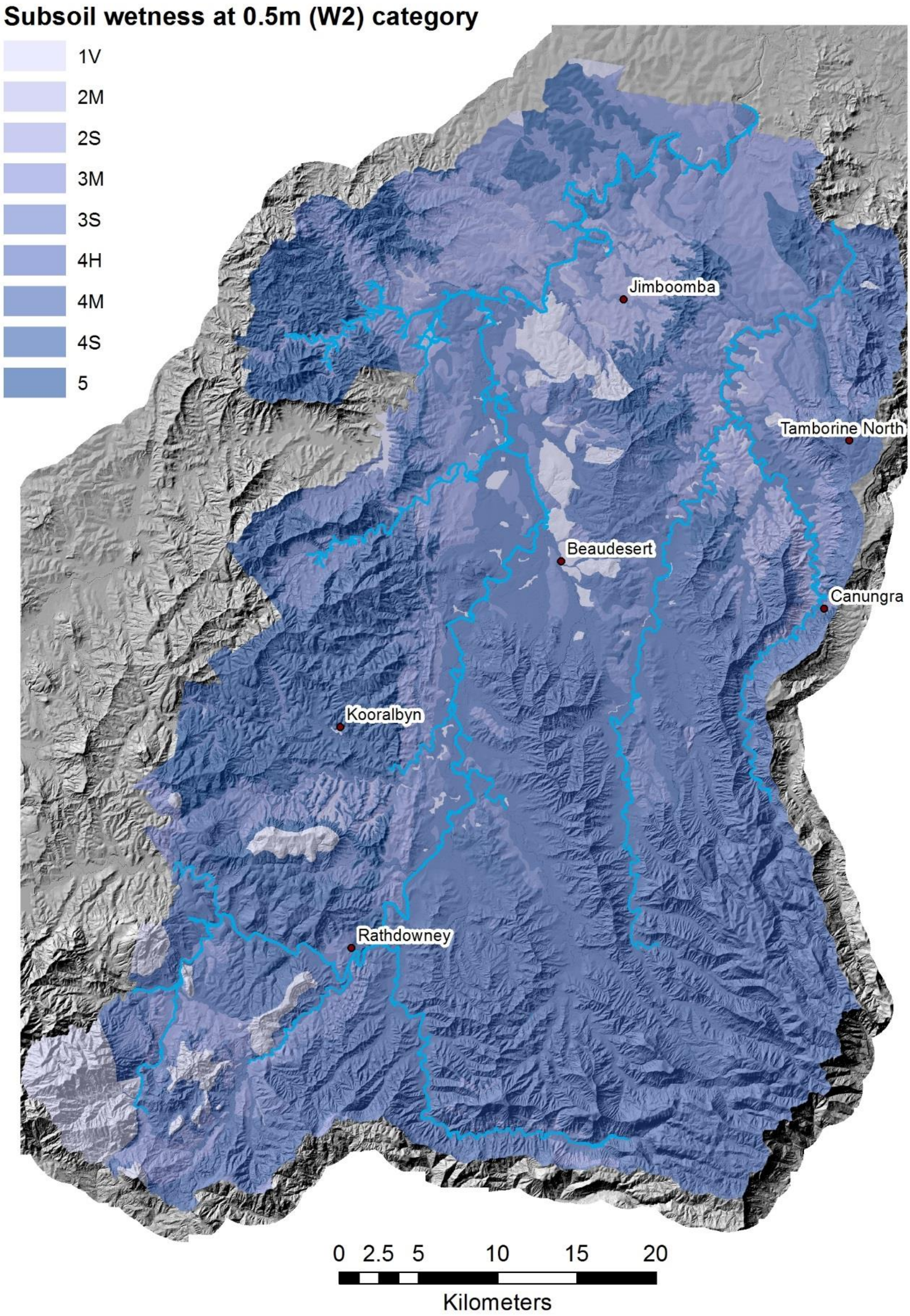


Figure 88. LARA subsoil wetness at 0.5m (W2) limitation categories.

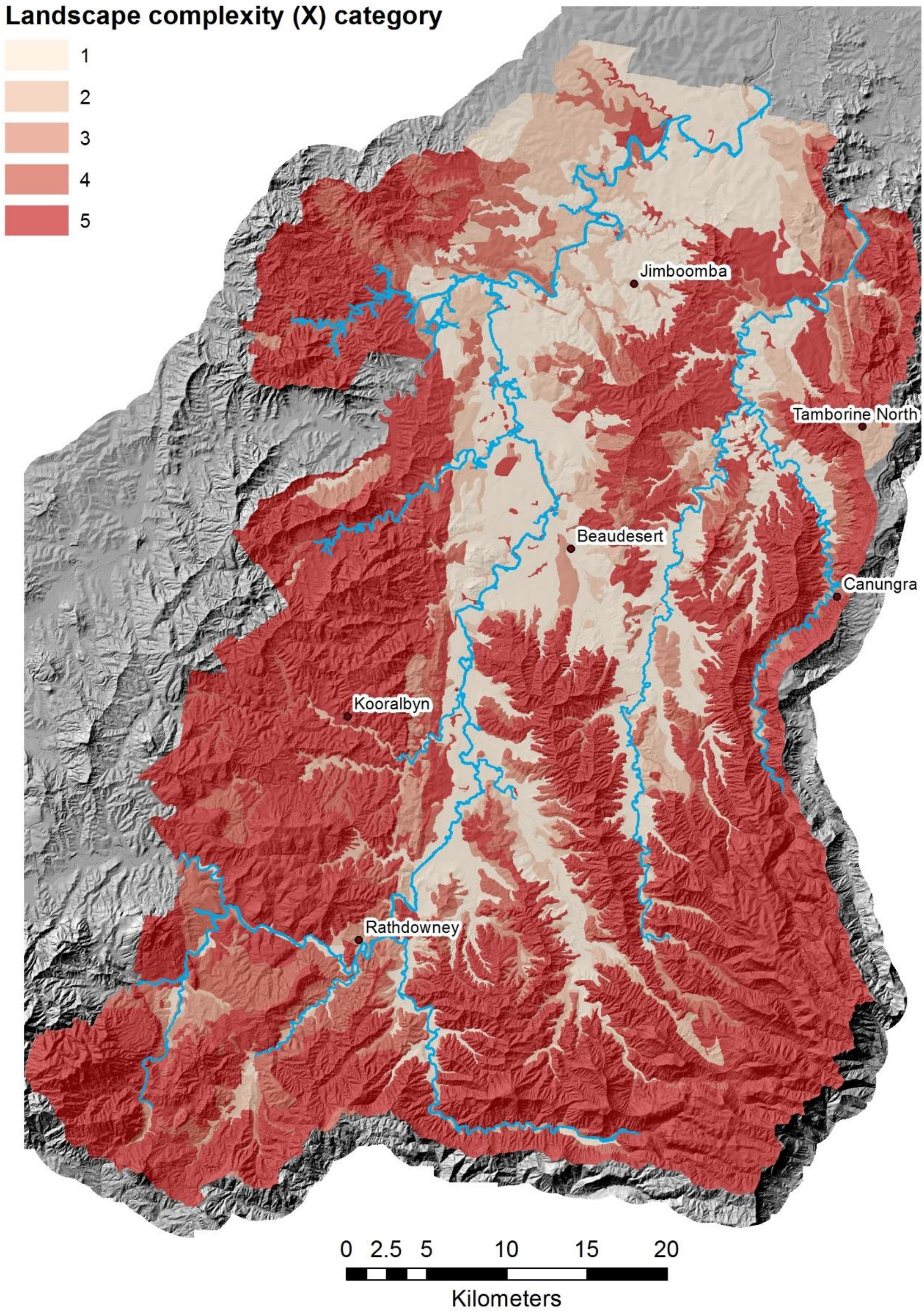


Figure 89. LARA landscape complexity (X) limitation categories.

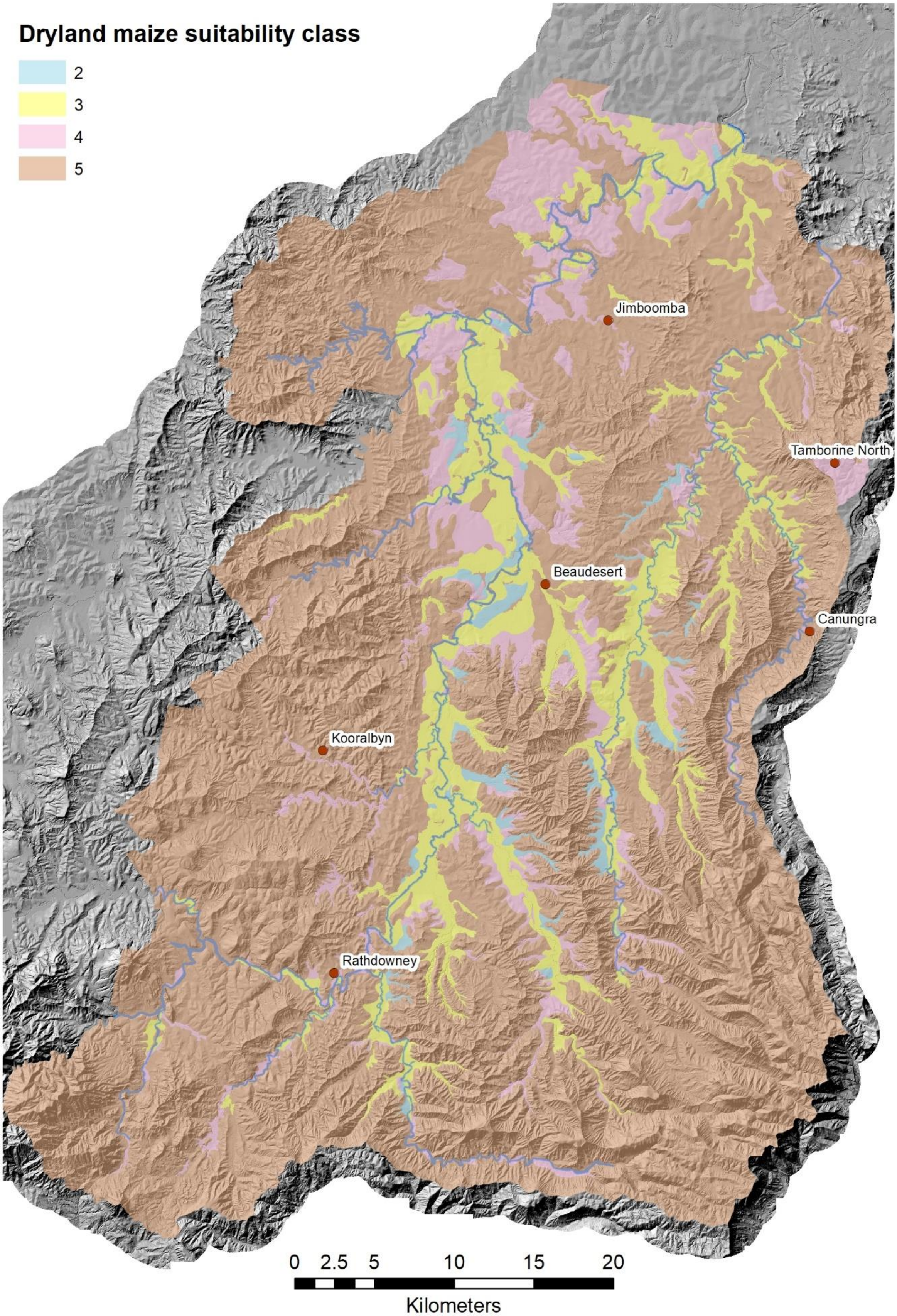


Figure 90. LARA agricultural land suitability classes for dryland maize.

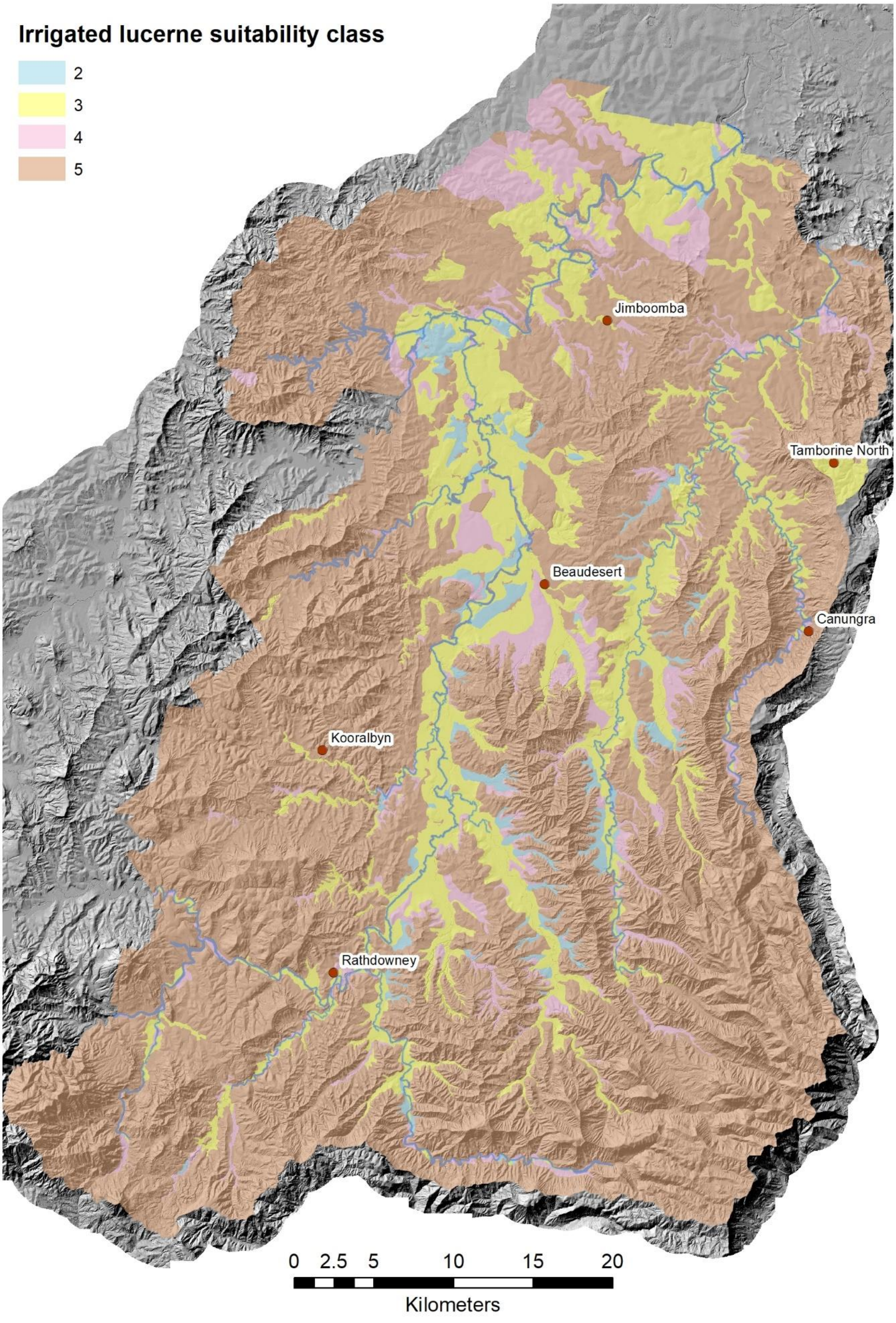


Figure 91. LARA agricultural land suitability classes for irrigated lucerne.

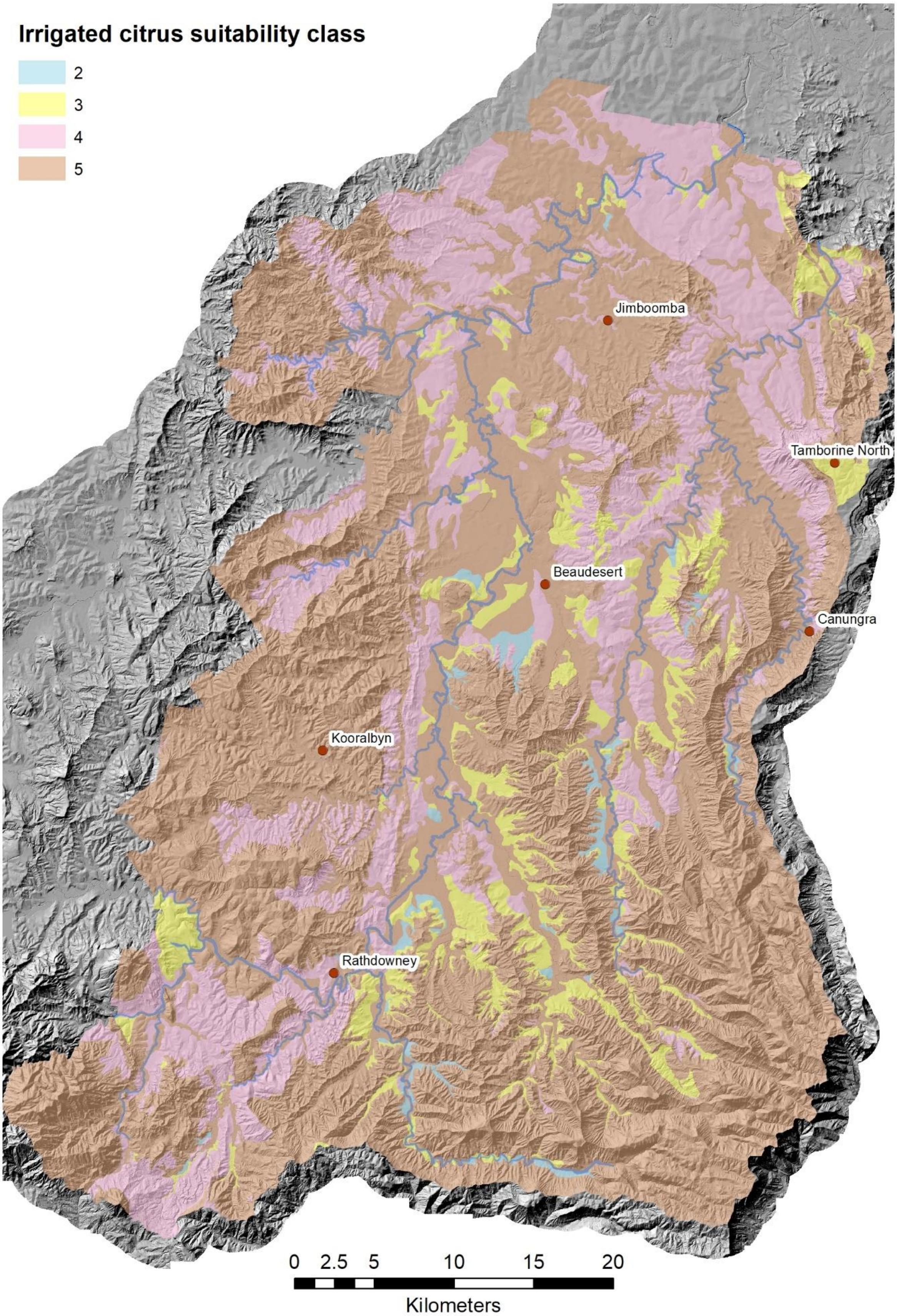


Figure 92. LARA agricultural land suitability classes for irrigated citrus.

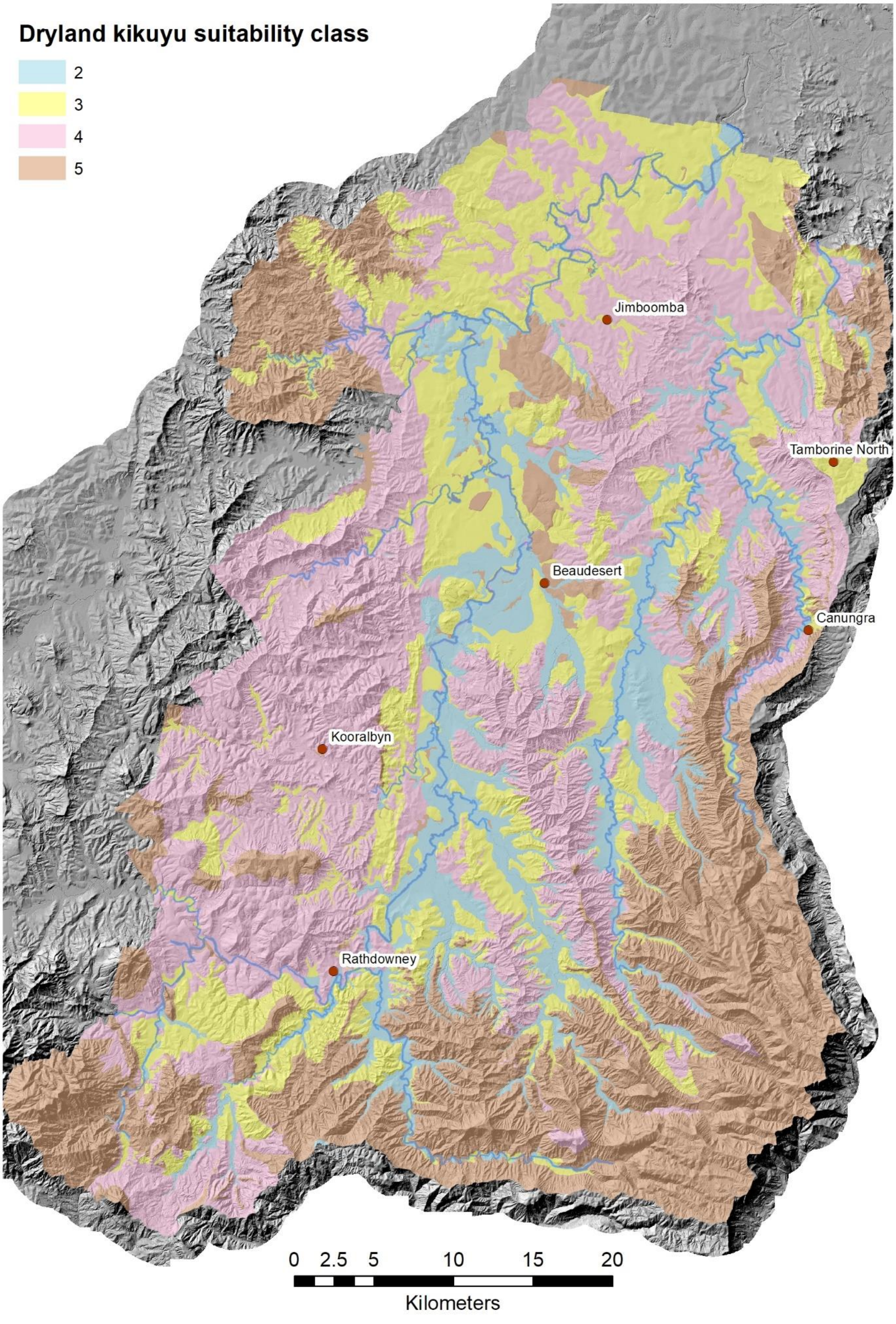


Figure 93. LARA agricultural land suitability classes for dryland kikuyu.

12.1 Additional erosion suitability considerations

The assessment of the soil erosion (E) limitation in this study is consistent with the surrounding soil surveys (BNH & SEQ). However, following a recent review focused on improving the quality of runoff water leaving agricultural areas a revised assessment of the soil erosion risk (E) limitation has been undertaken. This assessment used more conservative slope thresholds with the aim of reducing the export of sediment, nutrients and pesticides into waterways, off stream water storages and downstream estuarine environments.

While this more conservative E limitation has not been used in the derivation of land suitability for this project, the impacts of a modified E limitation has been considered. In the figures following (Figures 94-98), areas currently suitable for a selection of crops are shown along with areas (shown in red hatching) identified as being at higher risk of erosion.

All crop suitabilities would be subject to a reduction in suitable area under this modified E limitation, however, the areas most impacted include cultivated slopes around Tabragalba, Nindooinbah, Glenapp, Tamrookum, Christmas Creek, Upper Logan River and Veresdale.

Heightened consideration of erosion risk will not necessarily preclude these areas from agricultural production but it draws attention to areas where increased erosion awareness is warranted and where measures designed to minimise its impacts should be considered.

The Queensland Department of Environment and Science are currently undertaking a specific erosion study considering the impact of eroded sediment on waterways and water storages. Refer to this project for further information regarding these impacts.

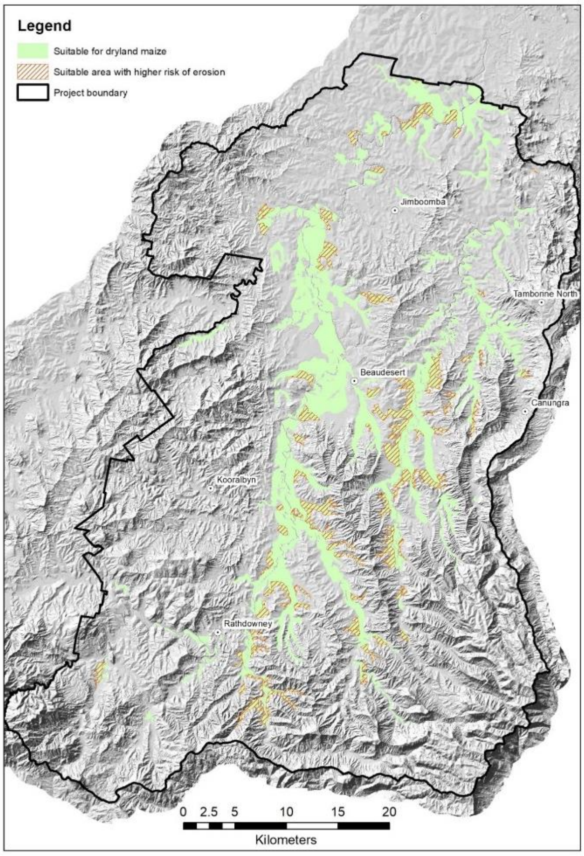


Figure 94. Areas of the LARA project suited to dryland maize but at higher risk of erosion

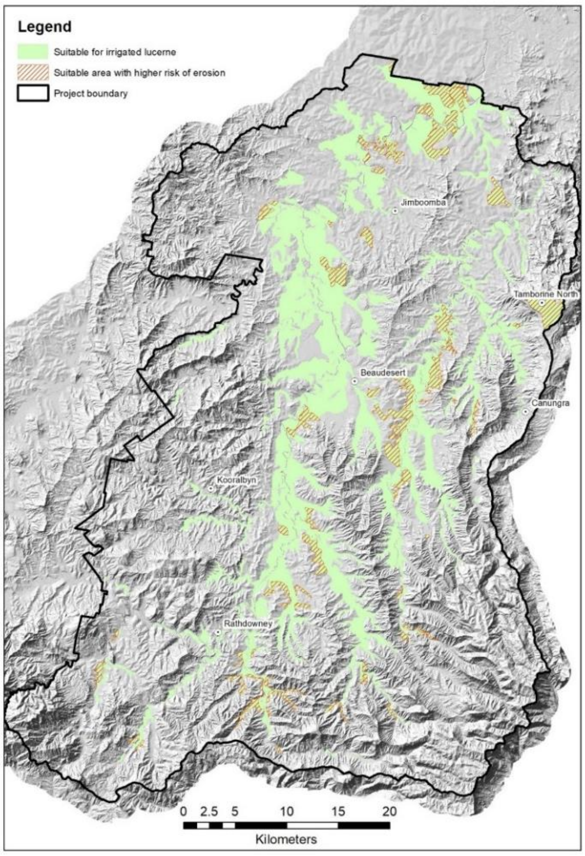


Figure 95. Areas of the LARA project suited to irrigated lucerne but at higher risk of erosion

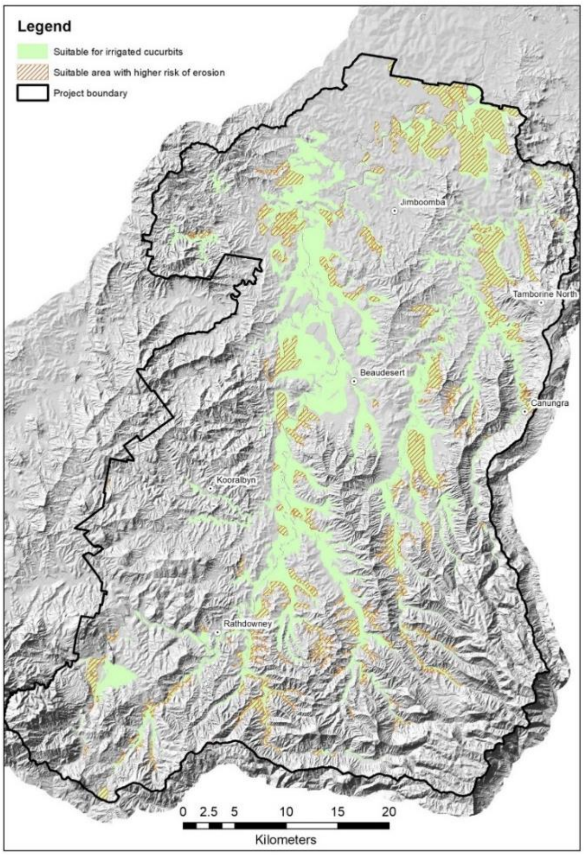


Figure 96. Areas of the LARA project suited to irrigated cucurbits but at higher risk of erosion

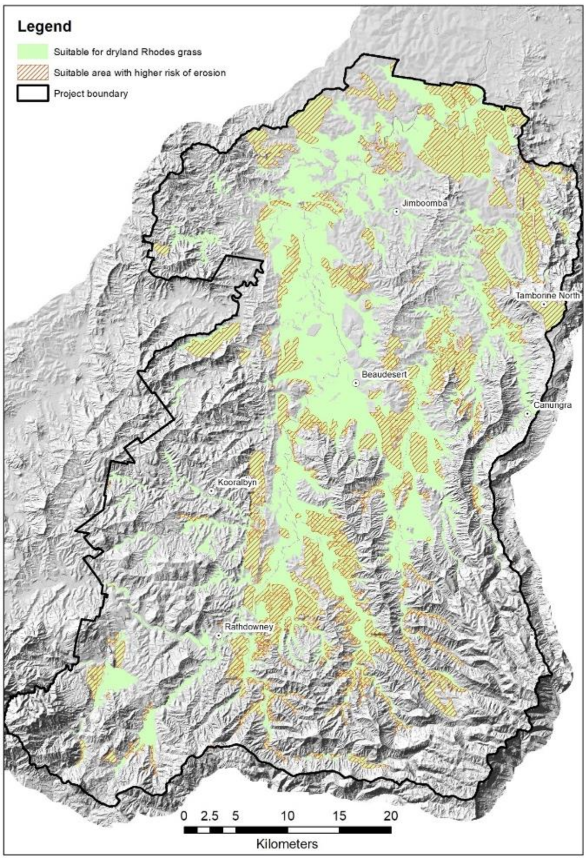


Figure 97. Areas of the LARA project suited to dryland Rhodes grass but at higher risk of erosion

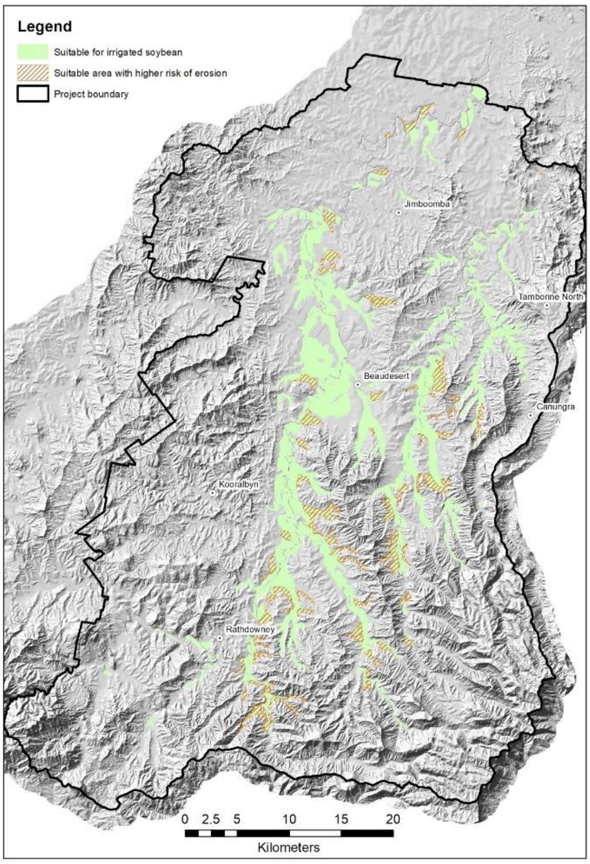


Figure 98. Areas of the LARA project suited to irrigated soybean but at higher risk of erosion

13. Agricultural land classification

Agricultural land classification follows a hierarchical scheme that indicates the location and quality of agricultural land. The classes imply a decreasing range of land use choice and an increase in the severity of limitations to sustainable production and/or land degradation hazard.

Class A land has the greatest potential for producing the widest range of crops, and has been subdivided into subclasses of A1 (land suitable for a wide range of broad acre crops) and A2 (land suitable for horticultural crops only)

Class B land is limited crop land (suitable for a narrow range of crops and pasture). Class C (pasture land) is subdivided into three subclasses. Class D land is unsuitable for agricultural use, including land alienated from agriculture due to inconsistent land use (e.g. urban areas, national parks). The four classes, and their subclasses, are summarised in Appendix 7.

From Table 66, 40 945 ha of the project area (15.85%) is suitable agricultural land (sum of classes A1, A2 and B). A further 127 680 ha (49.5%) is suited to grazing only (sum of classes C1, C2, C3 and 50% of the C3/D area).

Table 66. Area of agricultural land class (ALC) and percentage of study area occupied

Agricultural land class	(ha)	%
A1 Crop land	25 411	9.85
A2 Horticultural crop land	8908	3.45
B Limited crop land	6626	2.56
C1 Pasture land	15 728	6.09
C2 Native pasture land	48 179	18.64
C3 Light grazing	36 933	14.29
D/C3 Light grazing/non-agricultural land complex	53 681	20.78
D Non-agricultural land	59 009	22.84
Water (Stream, Dams, Swamps)	3909	1.51

The majority of the class A1 lands exist along the flats and lower slopes adjacent to the Logan and Albert Rivers and their tributaries (especially Christmas Creek, Running Creek and Canungra Creek), on the colluvial slopes of Albert Basalt and on foot slopes of some of the Woogaroo sandstones (Figures 99-102).

Full definitions of the crops considered in this assessment and the number of suitable crops required to qualify for each class are provided in The *Regional Land Suitability Frameworks for Queensland* (Department of Natural Resources and Mines & Department of Science, Information Technology, Innovation and the Arts 2013) and *Guidelines for agricultural land evaluation in Queensland—2nd Edition* (Department of Science, Information Technology and Innovation & Department of Natural Resources and Mines 2015), relevant parts of which have been reproduced in Appendices 4, 5 and 7 in Volume 2.

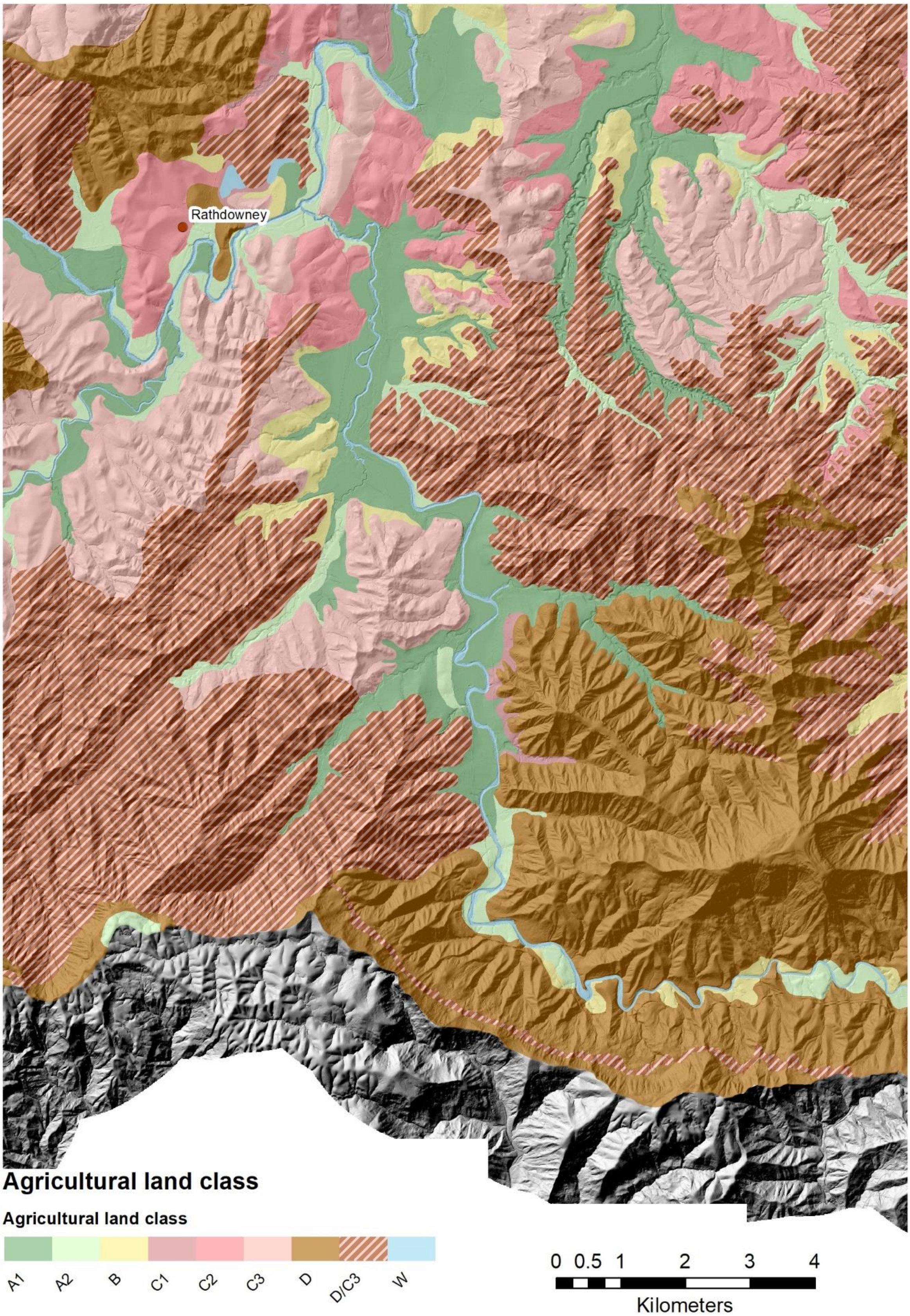


Figure 99. Agricultural land classes at Running Creek

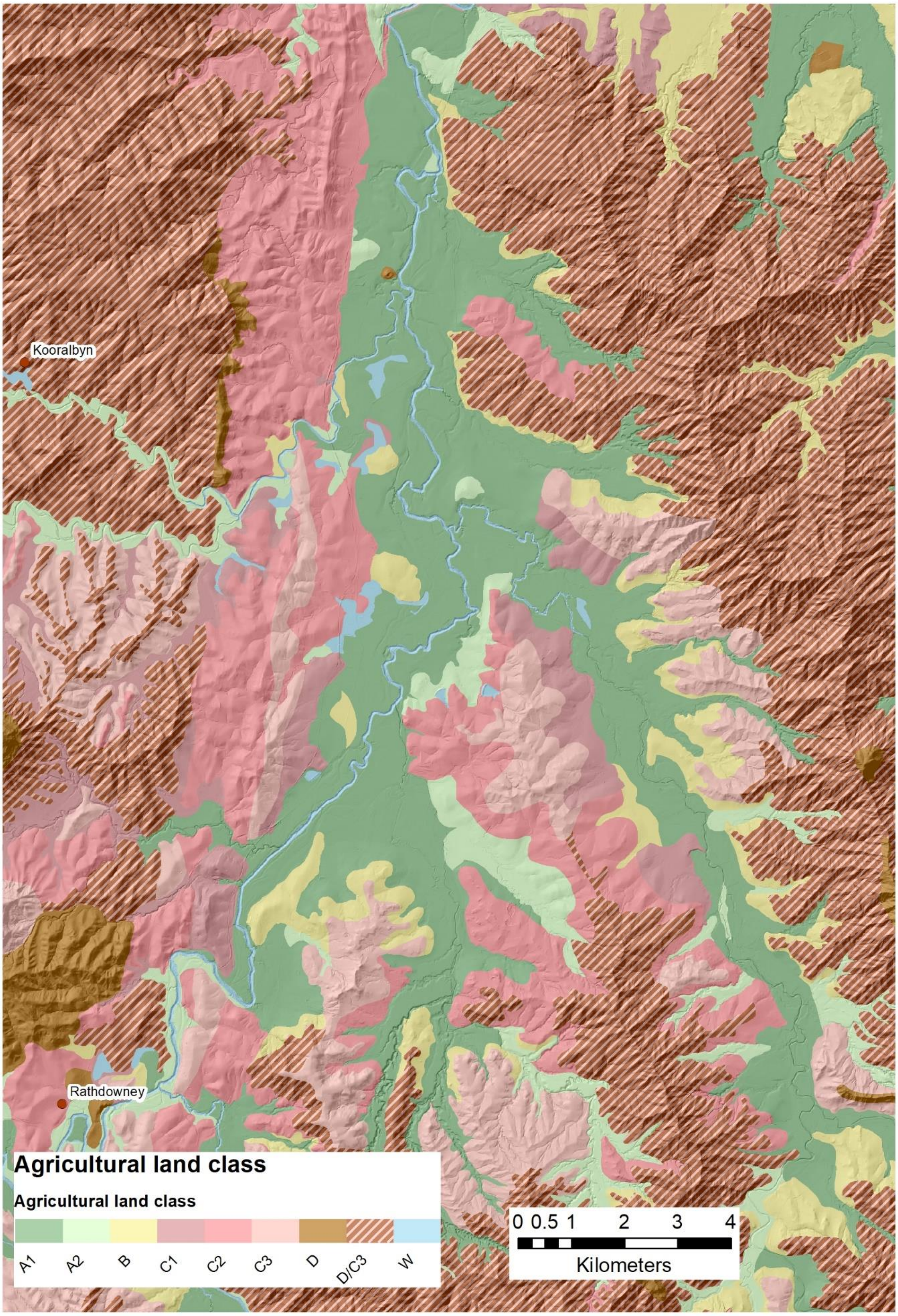


Figure 100. Agricultural land classes at southern Logan River and Christmas Creek

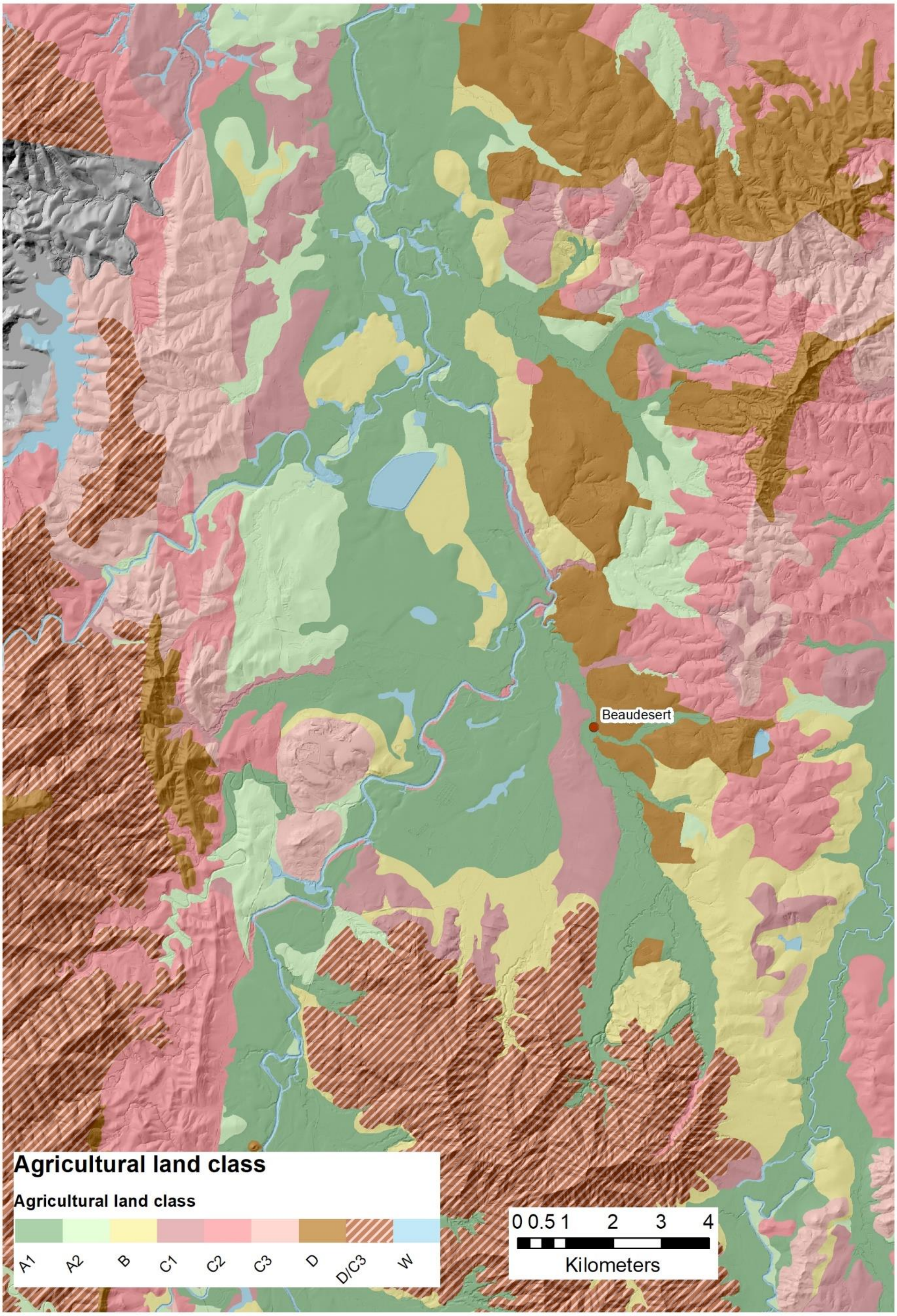


Figure 101. Agricultural land classes surrounding the Logan River at Beaudesert

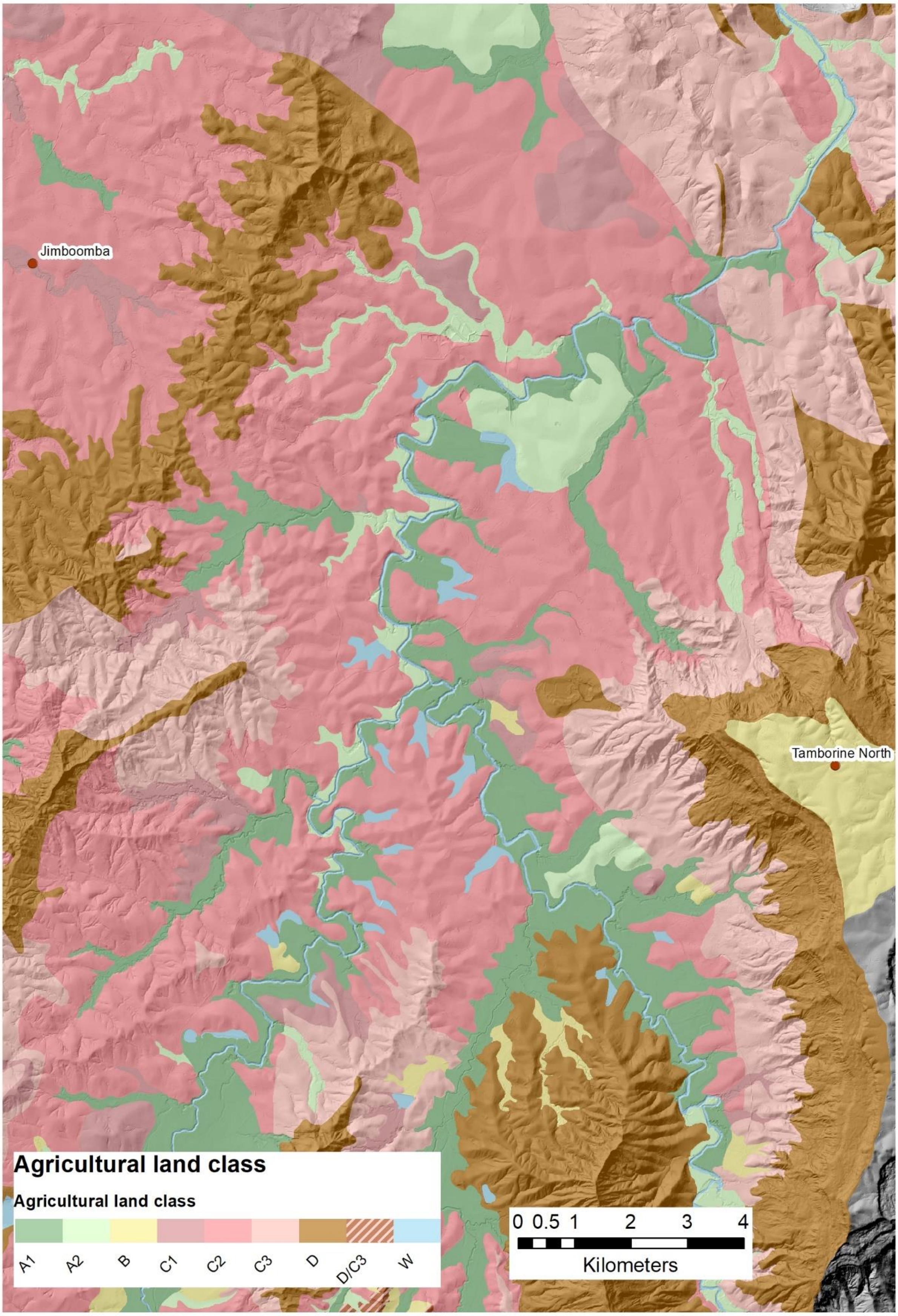


Figure 102. Agricultural land classes surrounding the northern Albert River

When additional areas alienated from agricultural use (including residential/rural residential, industrial, conservation, water bodies and public use areas) are considered, the available agricultural land is more accurately reflected, and reduced. These amended figures are listed in Table 67.

Table 67. Proportion of agricultural land classes after considering alienating land uses

Agricultural land class	Portion of study area after additional of agriculture alienating land uses included		Change to agricultural land class from Table 66	
	ha	**%**	**ha**	**%**
A1 Crop land	23 662	9.15	-1750	-6.88
A2 Horticultural crop land	7170	2.77	-1740	-19.5
B Limited crop land	5320	2.06	-1306	-19.7
C1 Pasture land	10 490	4.06	-5240	-33.3
C2 Native pasture land	34 472	13.33	-13 707	-28.45
C3 Light grazing	34 577	13.37	-2356	-6.38
D/C3 Light grazing/non-agricultural land complex	52 478	20.29	-1203	-2.24
D Non-agricultural land	86 554	33.47	+27 545	+46.68
Water (stream, dams, swamps)	3904	1.50	-5	-0.13

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Note: Updated data may be available at <http://qldspatial.information.qld.gov.au/catalogue//> or via <https://qldglobe.information.qld.gov.au/>