

Assessment of Agricultural Land Capability in Melbourne's Green Wedge and Peri-urban Areas

Agriculture Victoria Research Final Technical Report
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EXECUTIVE SUMMARY

Competing land uses, particularly urban development and rural living, can threaten agricultural production by resulting in the permanent loss of agricultural land; distorting rural land prices; fragmenting agricultural landscapes, and potentially creating conflict between farmers and 'lifestylers' due to dust, noise and odour associated with farming practices. *Plan Melbourne 2017-2050* reinforces the Victorian Government commitment to "protect agricultural land and support agricultural production" in Melbourne's green wedge and peri-urban areas (Policy 1.4.1, Action 17). This report details approaches used to assess agricultural land capability for agriculture in the Green Wedge and Peri-urban areas of Melbourne (land within 100 km radius of Melbourne's Central Business District). It presents information and maps covering Land Capability for intensive soil-based agriculture; key soils and landscapes; current intensive (higher-value) soil-based agricultural land uses and groundwater resources. This is in response to a request from the Victorian Department of Environment, Land, Water and Planning (DELWP) to prepare evidence to inform work to better identify areas of strategic agricultural land in Melbourne's Green Wedge and Peri-Urban area.

This project has assessed the capability of land for intensive soil-based agriculture production, rather than a focus on commodity-specific suitability, with prime determinants being soil and landscape factors. This approach has considered both productivity and sustainability factors (including landscape, soil quality, groundwater availability and quality and land degradation risk). Approaches used in other Australian states (e.g. WA, NSW, Queensland) to determine high-value agricultural land have been reviewed and briefly described in this report.

Key methodological components:

- Harmonisation of legacy mapping and data collation – involving the sourcing and standardisation of all available legacy soil and landscape mapping and associated data and descriptions of soil and landform.
- Delivery of soil and landscape attributes required by Deakin University for a separate land suitability assessment using an Analytic Hierarchy Process (AHP) approach.
- Determination of exclusion areas and special areas with land use implications for consideration.
- Land Capability Assessment – involving a methodology to rate each of the almost 1200 land mapping units according to four capability classes (*Class 1, 2, 3 and 4*) and exclusion areas (*Class 5*).
- Mapping current intensive land use (particularly horticulture and dairying).
- Mapping key soil types with strategic value for agriculture.
- Assessment of groundwater resources and opportunities to develop alternative water supplies.

Key deliverables:

- Landscape mapping units and associated soil and landscape attributes delivered to Deakin University (based on their specific modelling requirements).
- Land Capability map showing *Classes 1, 2, 3, 4 and 5* (excluded) land.
- Map of current intensive agricultural land uses (including horticulture, viticulture, cropping and dairying) for Melbourne's Green Wedge and Peri-urban areas.
- Maps of some key strategic soil types (i.e. Ferrosols, sandy soils and organic rich soils).
- Maps and description of groundwater resources.

This project has harmonised legacy mapping and collated all available soil and landscape data within Melbourne's Green Wedge and peri-urban zone. A Land Capability approach has resulted in the classification of mapped land units into five classes of which *Classes 1, 2 and 3* can be considered potentially suitable at this stage for future identification as 'Strategic Agricultural Land' (SAL), representing around 15% of the study area.

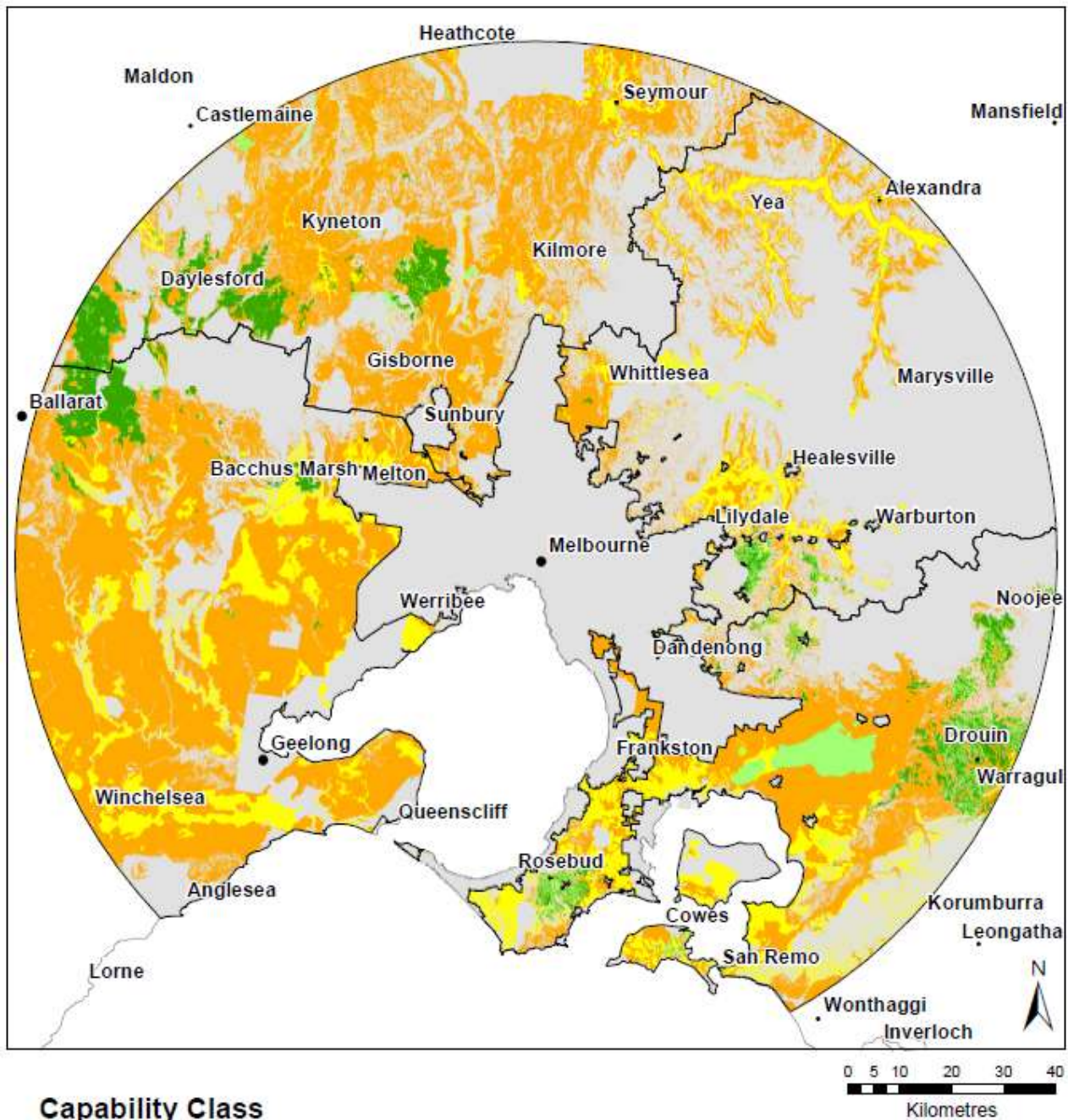
- **Class 1:** Land that is inherently capable for intensive soil-based agriculture, particularly horticulture. This class includes landscapes with Ferrosols on more gentle slopes and some alluvial areas. The access to a constant water supply will generally improve the capability of the land. Some land is included in this category due to improved land management (e.g. drainage, water access). Land management limitations are nil to slight. *Class 1* land covers around 3% of the total land area in the study area.

- **Class 2:** Land that is inherently capable for soil-based agriculture, including intensive horticulture and dairying. This class includes Ferrosols on steeper terrain (i.e. slopes >10%) and former swamp landscapes that have been extensively drained and have organic rich soils that also require adequate site drainage. Land management limitations are slight. *Class 2* land covers around 2% of the total land area in the study area.
- **Class 3:** Land that is inherently capable for soil-based agriculture at moderate to high intensity. The potential/capability may vary (e.g. according to slope, inherent fertility and drainage) but is often realised with access to a constant water supply. Many landscapes with deeper sandy soils are represented here – which are highly suited to horticulture once land-forming, drainage, fertilisers and irrigation is provided. Suitable landscapes with more favourable texture-contrast soils (e.g. deeper surface horizons, relatively friable and stable upper subsoils) are also included. Land management limitations are slight to moderate for intensive use. *Class 3* land covers around 9% of the total land area in the study area.
- **Class 4:** Land that is not as inherently capable for intensive soil-based agriculture. Extensive agriculture (including broadacre cropping with suitable land management practices) and non-soil utilisation activities are often most appropriate, and more intensive grazing is possible in some higher rainfall areas or where consistent water supplies are available. Due to mapping resolution, some minor exclusion areas (i.e. *Class 5*) can be present where land attributes (e.g. slope) vary locally. Land management limitations are high to very high for intensive use. There are also likely to be some areas of land within this Class that may have higher capability (e.g. suitable terrain with soils that have deep sandy surface horizons) but that are not able to be identified at this stage due to the broad scale of soil/landscape mapping available across much of the study area. *Class 4* land covers 36% of the total land area in the study area.
- **Class 5:** Land that is excluded from this study. This includes Public Land, areas within the Urban Growth Boundary (UGB), steep terrain (i.e. slopes >20% in landscapes with Ferrosols and slopes >10% elsewhere) and areas with potential Coastal Acid Sulfate Soils (CASS). *Class 5* land covers almost 50% of the total land area in the study area.

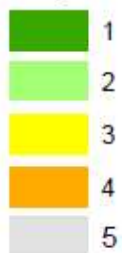
An assessment of current intensive agricultural land use and strategic soil types shows a strong association with many of the higher rated land capability areas. Land Capability provides the underlying foundation for the assessment of SAL. Deakin University's Centre for Regional and Rural Futures has undertaken a complementary and concurrent land suitability assessment ("*Land Suitability Assessment in Green Wedge and Peri-Urban Areas*") over a time horizon from present day to 2070. Suitability assessments for specific agricultural commodities can be useful to understand various potential land use options for this land, and factor in climate change projections. In addition, other non-biophysical criteria will also influence the designation of SAL, such as existing infrastructure, water supply and transport.

In areas close to Melbourne's urban area, Land Capability *Class 1, 2 and 3* land can be given groundwater resource condition status with high certainty where it falls within an existing Groundwater Management Area (GMA) and especially where there is currently licensed and utilised groundwater associated with allotments. Lower certainty applies where there are favorable Groundwater Flow Systems (GFS) mapped but an unproven resource, and a low likelihood of a viable groundwater resource applies to any identified Land Capability *Class 1, 2 and 3* land that overlies bedrock geology.

The land capability mapping is undertaken at a broad regional scale. There may be circumstances in which the maps presented in this report, based on available data, do not reflect the on-ground agricultural activity of a site. The intended use of this analysis is to inform regional-level planning rather than farm-level decision-making. Combining land suitability mapping (Deakin University) with the land capability mapping, detailed in this report, can provide a foundation to understand the existing and potential future context of strategic agricultural land in Melbourne's Green Wedge and Peri-Urban Areas.



Capability Class



Note: Land capability analysis is based on available soil and landscape mapping and data, which varies in scale and quality across the study area. It provides an indication of likely capability based on existing information and provides a useful basis for further finer-scale assessments. A detailed on-site assessment of the soil and landscape should be carried out prior to any proposed development taking place.

1. INTRODUCTION

This report details approaches used to assess land capability for soil-based agriculture in the Green Wedge and Peri-urban (land within a 100 km radius from the Central Business District) areas of Melbourne. It presents information and maps covering land capability for intensive agriculture; key soils and landscapes; current higher-value agricultural land use and groundwater resources within the peri-urban zone. This is in response to a request from the Victorian Department of Environment, Land, Water and Planning (DELWP) to prepare evidence to inform work to better identify areas of strategic agricultural land in Melbourne's Green Wedge and Peri-Urban area.

The Victorian Government's metropolitan planning strategy, *Plan Melbourne 2017-2050* sets out the government's long-term plan to accommodate Melbourne's projected growth in population between now and 2050 whilst enabling Melbourne to grow more liveable, more sustainable and more prosperous. It outlines the government's policy positions to maintain a permanent urban growth boundary to contain Melbourne's outward growth and commits to "protect agricultural land and support agricultural production" (Policy 1.4.1). To deliver on this policy, the Plan Melbourne Five Year Implementation Plan includes Action 17, which states:

Plan Melbourne Action 17 - Support strategic planning for agriculture

Improve planning decision-making to support sustainable agriculture by identifying areas of strategic agricultural land in Melbourne's green wedges and peri-urban areas. This will give consideration to climate change, soils and landscape, access to water, integration with industry and significant government investment in agricultural infrastructure. It will also protect the right to farm in key locations within green wedges and peri-urban areas.

1.1 Background

Competing land uses, particularly urban development and rural living (e.g. Plate 1), can threaten agricultural production by resulting in the permanent loss of agricultural land (e.g. Plate 2); distorting rural land prices; fragmenting agricultural landscapes, and potentially creating conflict between farmers and 'lifestylers' due to dust, noise and odour associated with farming practices.



Plate 1. Agriculture surrounding Lancefield (Photo: Mark Imhof)



Plate 2. New urban development at Clyde in what was a former extensive vegetable cropping area (Photo: Mark Imhof)

This report assesses Land Capability for higher-value agriculture production, rather than a focus on commodity-specific suitability. Prime determinants are soil and landscape, with consideration given to groundwater resources and climate. This approach considers both productivity and sustainability factors (including landscape, soil quality, groundwater availability and quality and land degradation risk). In developing the approach to this assessment, consideration has been given to approaches used in other Australian states (e.g. WA, NSW, Queensland) to determine high-value agricultural land. Land capability analysis is based on available soil and landscape mapping and data which varies in scale and quality across the study area. It provides an indication of likely capability based on existing information and a useful basis for further finer-scale assessments. A detailed on-site assessment of the soil and landscape should be carried out prior to any proposed development taking place.

Agriculture Victoria Research (AVR) is the Victorian Government custodian for soil and land data and information and has specialist skills in its interpretation and mapping. Key staff involved in this project include Mark Imhof and David Rees (both Certified Professional Soil Scientists) and Dr Bruce Gill (Senior Hydrogeologist). Wayne Harvey and Don Cherry provided spatial analysis and mapping expertise.

1.2 Land evaluation approaches

Rule based methods have dominated land evaluation for several decades and continue to be useful (van Gool et al 2008), particularly if expert knowledge is applied. A range of approaches have been used to determine the capability and/or suitability of land, including:

- Most Limiting Factor (MLF).
- Parametric (e.g. Storie Index).
- Expert opinion systems, including Analytic Hierarchy Process (AHP).

The Most Limiting Factor (MLF) approach has been the most widely used in Victoria due to its simplicity and clarity of approach, identifying the most limiting factor for a designated use, and providing the opportunity to suggest measures that could enhance the capability of that land unit. The Parametric approaches usually combine assigned scores according to each factor assessed. This gives a basis for relating different units and landscapes but is often subject to perceived weighting assigned to particular factors (e.g. is low permeability equivalent to high nutrient status or "x" times as important to plant growth?).

Expert Opinion Systems work along the lines of the Parametric approach but instead on a probability basis using a binary/Bayesian framework (e.g. is factor 'A' more important than factor 'B'?). This is followed by what proportion of A or B is divided into classes e.g. pH classes that will vary for different crops. The Analytic Hierarchy Process (AHP) has been used to assess crop suitability using both biophysical and plant requirements with the input of expert opinion rather than trial information *per se*.

The difference between land capability and suitability approaches

The FAO Framework developed by the Soil Conservation Service of the United States Department of Agriculture (USDA), as outlined by Klingbiel and Montgomery (1961), was considered a substantial improvement from previous systems used for land evaluation. The prime aim of this approach was to assess the degree of limitation to use imposed by land characteristics that were considered virtually permanent and interpret information obtained from the detailed (1:20 000 scale) county soil surveys in a way that could be readily understood by a range of users including farmers and planners. It focuses on agriculture, more broadly, and does not provide an explicit basis for assessing trade-offs between competing land uses (van Gool et al., 2008). FAO (1976, 1983) defines land suitability as the 'fitness' of a land type for a *specified* land use.

The implication of Land Capability Assessments (LCAs) is one of scale and potential rather than 'suitability' which traditionally factors in other variables such as access and infrastructure as well as specific requirements for specific crops/outputs. When dealing with specific agricultural land uses (e.g. a specific crop type) then climatic factors are also important for determining land suitability. Traditionally LCAs have been developed at the 1:25 000 scale which coincides with Urban/Rural Planning scales of operation (<= 1:40 000). Smaller scales (i.e. broader-scale assessments) are often too general for many landscapes and do not factor in the, often, large variability in some land attributes. The broader scale studies are, however, very useful in highlighting areas of potential.

Land Capability identifies potential of an area of land for different uses or management practices. As the information can be presented in a non-technical way, Land Capability has gained wide acceptance and adoption from a range of users that include planners, land managers and farmers (Brown et al. 2008). Land capability assessment is based on intrinsic biophysical limitations of the land, i.e. those that act as constraints, and cannot be readily removed or ameliorated by reasonable management (and with an economic cost).

Land Capability also assesses the ability of the land to sustain land use without irreversible land degradation occurring. Before land capability ratings can be used for planning purposes they should ideally be subject to suitability assessment that involves consideration of socio-economic factors that may influence a specified land use. An agricultural capability rating, for example, will most likely not change significantly over time, whereas agricultural suitability may change if product demand or factors relating to its location change (e.g. availability of water). The concept of Land Capability is often linked to the concept of 'versatility'; whereby the better the capability, the more land use options (including higher-value uses) are possible. Traditionally this has been a five-class system as compared to 'Land Classing' which is generally an eight-class system. In New South Wales (NSW) an eight-class system is used and updated (Office of Environment and Heritage, 2012).

High Land Capability (LC) for land should have dominant soils in terms of capability (potential) that are:

- Adequately drained but can still hold sufficient moisture as well as nutrients (important for biomass production but also for minimising off site effects). This generally implies well-developed and favourable structure/friability.
- Deep enough to provide plant support with few restrictions to root and water movement down the soil profile.
- Able to adequately cope with traffic (i.e. are reasonably resilient to physical disturbance).

Potential areas can become capable with increasing management intervention and infrastructure (e.g. drainage, addition of organic matter). Water supply is also crucial for intensive uses, either natural or artificial, to convert 'potential' into 'suitable'. These premises still hold with changing climate, but boundaries of potential may shift.

Van Gool et al. (2008) describe the advantages and disadvantages of land capability and suitability approaches. A key disadvantage is that a map of land suitability often fails to provide the land manager or planner with the information they need; and potential land management options are often 'lost' in the final ratings. Assessments of land capability/suitability also usually depict 'crisp' classes with sharp boundaries when variation in many landscapes is continuous.

Considering the diverse agricultural uses of soils (e.g. growing different crops with dissimilar soil requirements) and the different optima associated with each specific use, Sojka and Upchurch (1999) emphasise the importance of understanding rather than rating the soil resource in terms of soil quality. In this report we have taken an approach where we provide an assessment of land capability for higher-value agriculture, together with descriptions of the actual soil, land types and hydrogeological resources that ultimately need to be managed on-site. This then forms a useful basis for then further assessing various agricultural options and climate change scenarios (e.g. as determined by the Land Suitability approach being undertaken by Deakin University) in determining 'Strategic Agricultural Land'.

Previous agricultural land assessments in Victoria

Guidelines for Land Capability in Victoria were developed by the former Soil Conservation Authority (SCA) as described by Rowe et al. (1981). This has been used and modified by subsequent State Government groups, to develop the series of Land Capability Assessments (LCAs) for areas along the Melbourne-Bendigo corridor as well as around peri-urban Melbourne in the 1990's. A desk-top study on identifying and conducting a preliminary risk assessment of prime development zones in the greater Melbourne area for recycled water use was undertaken by the former Centre for Land Protection Research (DNRE, 2004).

A 'Review of Rural Land Use in Victoria' (1991) was prepared by the former Department of Agriculture and Department of Conservation and Environment. It defined 'prime agricultural land' as "*land that has deep, well drained soils capable of regular cultivation in areas with minimal slopes and with good growing seasons for a range of crops due to advantageous climate and supporting infrastructure*". These lands are usually capable of supporting, on a continuing basis, a high level of production for a range of crops. The definition covers land where intensive horticulture either occurs or else has the potential to be carried out.

The former Department of Agriculture and Rural Affairs (Swan and Volum, 1984) developed and applied an assessment technique for the Gippsland region which was used by local and regional planning authorities in Gippsland at the time to develop their rural policies.

More recently, Dr Ian Sargeant, on behalf of the Victorian Eco-Innovation Lab, University of Melbourne (2013), provided a LCA for peri-urban Melbourne for VicHealth. This was limited to the eastern part of the peri-urban area where he had previously carried out much of the base soil-landscape mapping.

1.3 Australian approaches to assess the significance of agricultural land

Various Land Capability approaches have been used to assess significant agricultural land in other Australian states. In Western Australia, Land Capability assessments of soil-landscape mapping units have formed an integral part of the process of identifying 'High Quality Agricultural Land' (HQAL). A recent assessment in the Geraldton Planning region (Tille et al., 2013) identified HQAL that exhibits a combination of qualities valuable to the agriculture industry and worthy of protection for future production potential. It synthesized a range of land capability, water resource and other data related to land use into a more readily understood format that could be readily incorporated into the planning process. It aimed to reduce the number of complex-style maps, while making the simplified mapping more definitive. 'Land flexibility' was an important consideration in this approach. The NSW Department of Planning and development undertook an assessment of 'Biophysical Strategic Agricultural Land' (BSAL) beginning in 2013. These lands intrinsically have the best quality landforms, soil and water resources that are inherently capable of sustaining high levels of productivity and that require minimal management practices to maintain this quality. BSAL is capable of being used sustainably for intensive uses such as cultivation. Queensland also has a process for the identification of 'Strategic Cropping Land' (SCL) which is based on eight soil and landscape criteria. Appendix 1 of this report provides extended detail on these various state approaches.

2. METHOD

The seven key components of this study, focused on the Green Wedge and Peri-urban area (100 km radius from Melbourne), have been:

- Harmonisation of legacy mapping and data collation – involving the sourcing and standardisation of all available soil and landscape mapping and associated data and descriptions of soils and landforms.
- Delivery of soil and landscape attributes specifically required by Deakin University for their land suitability assessment of specific agricultural commodities using an Analytic Hierarchy Process (AHP) approach.
- Determination of exclusion areas and special areas for consideration with land use implications.
- Land Capability Assessment – involving a methodology to rate each mapped polygon according to five capability classes.
- Mapping current agricultural land uses (cropping and dairying).
- Mapping key soil types with strategic value for agriculture.
- Assessment of groundwater resources.

2.1 Harmonising legacy mapping and data collation

The 100 km peri-urban zone has a variety of legacy land mapping studies carried out between early 1970s (e.g. Upper Yarra and Dandenong Ranges study) to the mid-2000s (e.g. Corangamite Land Resource Assessment study). These vary in nature from broad Land Systems mapping to more detailed soil/landscape mapping. Figure 1 provides an overview of the extent of legacy surveys, their mapping scale and the intensity of available soil site data. Many of these legacy reports are available via the Victorian Resources Online (VRO) website at <http://vic.gov.au/vro>. Appendix 2 of this report provides a listing of all the legacy surveys assessed and direct links to the VRO website where relevant information can be found.

Map scale indicates the relationship between a unit of length on a map versus the length that this represents on the ground. At a mapping scale of 1:100 000, 1 cm on the map represents 1 km on the ground. A 'Land System' is an area of land, distinct from the surrounding terrain, that has a specific climatic range, parent material and landform pattern. These features are expressed as a recurring sequence of land components. Land System mapping is generally conducted at a scale of 1:250 000 and is most appropriate for smaller (i.e. broader) scale planning exercises, such as regional planning. 1:100 000 scale mapping is often referred to as soil/landscape mapping. A land component is an area of land, distinct from adjacent components because of specific slope, soil, aspect and/or vegetation characteristics. A land capability mapping unit may be the same as a land component; however, a larger (i.e. more detailed or finer) mapping scale may allow land components to be separated into distinct areas based on more specific soil and topographical characteristics. The least reliable studies are those at broader mapping scales (i.e. 1:250 000 or smaller) with limited soil site observations. Other surveys (e.g. former Shire of Romsey) are based on more detailed landscape mapping

(i.e. 1:25 000 scale) but have fewer soil site observations relative to that scale and are therefore more equivalent to a broader scale (i.e. 1:50 000 or greater) assessment. The mapping of the Cranbourne to Koo-Wee-Rup region, at a scale closer to 1:25 000, is based on many soil site observations and is therefore considered more reliable, despite the limited number of key reference sites (with detailed analytical data). Maps at scales of 1:100 000 or smaller are best suited to broad-scale strategic planning, not to property-specific planning.

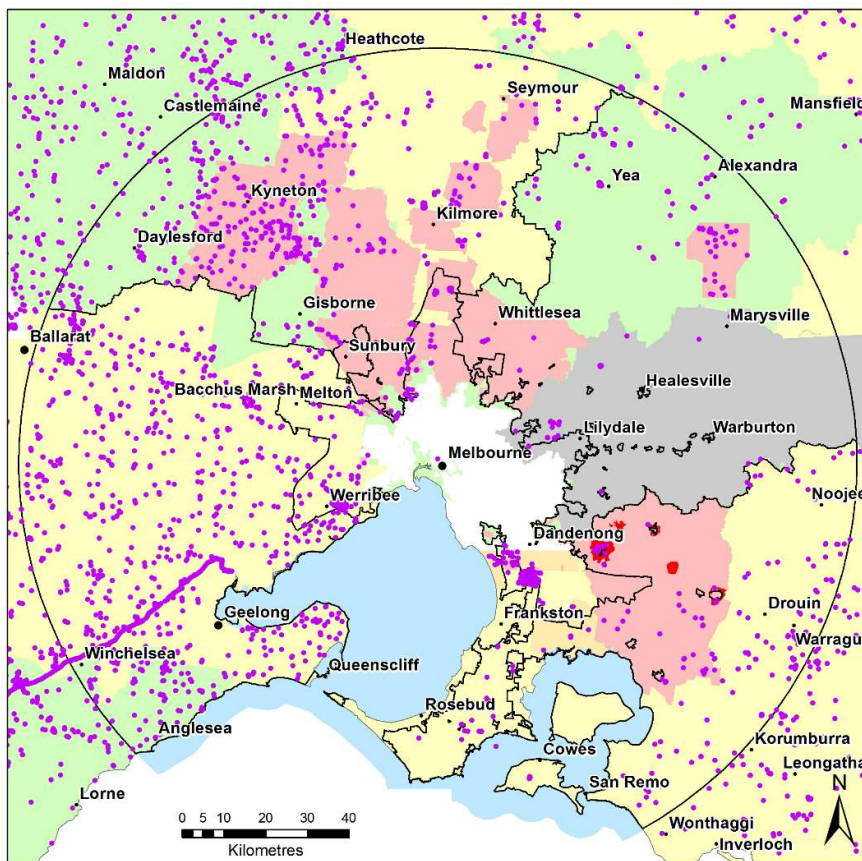


Figure 1. Extent of legacy surveys, mapping scales and intensity of soil site data.

Mapping scale of legacy surveys

Study	Scale
Upper_Yarra_Valley_Dandenong_Ranges_Land_systems	1:60000
Ballan_land_systems	1:250000
Bannockburn_land_system	1:100000
Bungaree_land_systems	1:100000
Campaspe_river_catchment_land_systems	1:250000
Cardinia_Land_Units10k	1:10000
Cardinia_Land_Units25k	1:25000
Cathedral_Ranges_Acheron_Valley_Land_units	1:25000
Corangamite_land_units	1:100000
Cranbourne_KooWeeRup_land_units	1:50000
Eildon_land_systems	1:250000
Euroa_south_land_units	1:100000
Gippsland_Lakes_Catchments_Land_systems	1:100000
Gippsland100_Land_Units	1:100000
Goulburn_Broken_Land_units (Freehold)	1:100000
Landsystems_of_Victoria	1:250000
Greater_Melbourne_land_units	1:100000
Loddon_River_map_units	1:250000

	1:10000		1:60000	• Soil sites
	1:25000		1:100000	
	1:50000		1:250000	

Study	Scale
Melbourne_LRDA	1:25000
Melbourne_northern_hinterlands_land_systems	1:250000
Mid_Goulburn_Land_units	1:250000
Mitchell_Shire_Land_units_100k	1:100000
Mitchell_Shire_Land_units_25k	1:25000
Murrindindi_Shire_Land_units	1:100000
Newham_Woodend_Land_units	1:25000
Otway_Ranges_Land_systems	1:250000
Romsey_Land_units	1:25000
South_West_Gippsland_Land_Units	1:100000
Westport_Catchment_Land_units	1:100000
Whittlesea_Land_unit_capability	1:25000
South_West_Victoria_Land_units	1:250000
Kyneton_Land_units	1:25000

The Green Wedge and Peri-urban areas consist of

1200 individual map-units derived from legacy surveys and almost 64,000 individual mapped polygons.

Considerable time was required in this study to harmonise mapped polygons, including edge-matching and attribution for key soil and landscape properties.

2.2 Delivery of mapping and soil and landscape attribute data to Deakin University

Soil property attributes (pH, EC, sodicity, dispersion, drainage characteristics) required for Deakin University land suitability modelling were determined for surface and upper subsoil horizons for each of the 1200 map units. Attributes were generally determined for the dominant soil type represented in each map unit. Where adequate data was available then value estimates were provided; however, in areas with limited data relative only estimates were provided. Mapped polygons and associated soil and landscape attributes were provided in four tranches for each of the four zones – south-east (9/2/18), north-east (19/3/18), north-west (25/4/18) and south-west (4/6/18). Agriculture Victoria had no further input in to the suitability assessment for various agricultural commodities.

2.3 Determination of exclusion areas and areas for special consideration

Public land and areas of land within the designated Urban Growth Boundary (UGB) have been excluded from this Land Capability study (Figure 2). Certain areas of private land have also been excluded due to landscape constraints or potential threats. Key factors considered are steep slopes and potential Coastal Acid Sulfate Soils (CASS) as shown in Figure 3. Certain existing land uses that preclude agriculture (e.g. urban areas, extractive industries) have not been considered at this stage.

Slope

A greater than 10% slope limit has been adopted as a general cut-off, apart from a 20% slope cut-off for landscapes with Ferrosols as the dominant soil type. In Land Capability studies conducted elsewhere, 10% has generally been used as a cut-off slope value for various land use activities. The NSW land capability mapping scheme, for instance, considers that 10% is the average upper limit for cultivation on most soils. On more fertile and stable soils of basaltic origin (i.e. Ferrosols) this may rise to 20% while for poorer sodic soils (e.g. Sodosols) it may fall to 5% but these poorer soils are often unlikely to be considered areas of high agricultural land capability and have not been considered in this study. Some landscapes (such as the rolling hills developed on Cretaceous sediments in the Strzelecki Ranges in Gippsland and weakly structured sandy soils on granite slopes) are considered more susceptible to erosion, including tunneling and/or landslips, so a 10% slope cut-off is appropriate. Vegetation cover is a key determinant for assessing erodibility, combined with soil properties and slope. It is, however, a dynamic factor that is largely dependent on management and not practical to consider in such an assessment.

Acid Sulfate Soils

Coastal acid sulfate soils (CASS) occur naturally along many parts of Victoria's coastal zone and, if left undisturbed, are largely benign. However, if disturbed, i.e. water drains from the soil and air enters, they can react with oxygen and produce sulfuric acid. This can be detrimental to the environment with impacts that include acidification of water and soil, de-oxygenation of water, poor water quality, dissolution of soil, rock and concrete, and corrosion of metals. Areas mapped along the Victorian coast that have potential to become CASS have been excluded from the land capability assessment (i.e. orange coloured areas in Figure 4). Refer to: http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_acid_sulfate_soils

Declared Water Supply Catchments and Special Area Plans

Many catchments supplying water for domestic, irrigation or other purposes within Victoria are protected under the *Catchment and Land Protection Act 1994*. These catchments have significant values as a source of water supply, both for domestic and for stock and domestic use. We have not excluded these areas from the land capability assessment, but this information assists planners and those managing land disturbance or development activities to readily determine the suitability of proposed activities within these areas. Once a catchment is 'Declared', approvals for activities conducted under other statutes and statutory planning schemes must be referred to the responsible land management authority (CMA or DELWP) for approval.

Special Area Plans (formerly known as Land Use Determinations) have been developed for some Declared Water Supply Catchments. These catchment land use and management plans specify where (location) various land uses may be undertaken and how (conditions of use) they should be undertaken, to minimise any adverse effects on water related values. Special Area Plans are developed where catchments are exposed to

sufficient pressure. Refer to: <http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/landuse-water-supply-catchments>

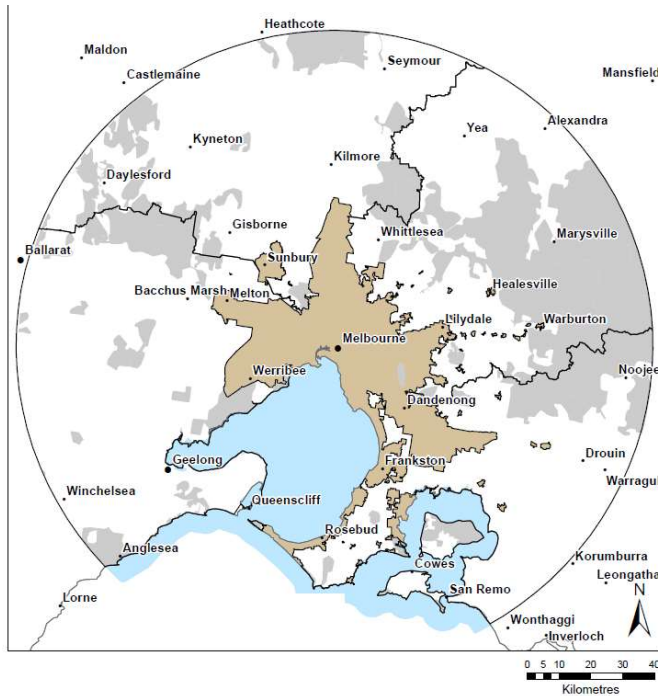


Figure 2. Areas excluded from Land Capability assessment – Public Land and Urban Growth Boundary (UGB).

Areas excluded from Land Capability Assessment

- Public land
- Urban Growth Boundary

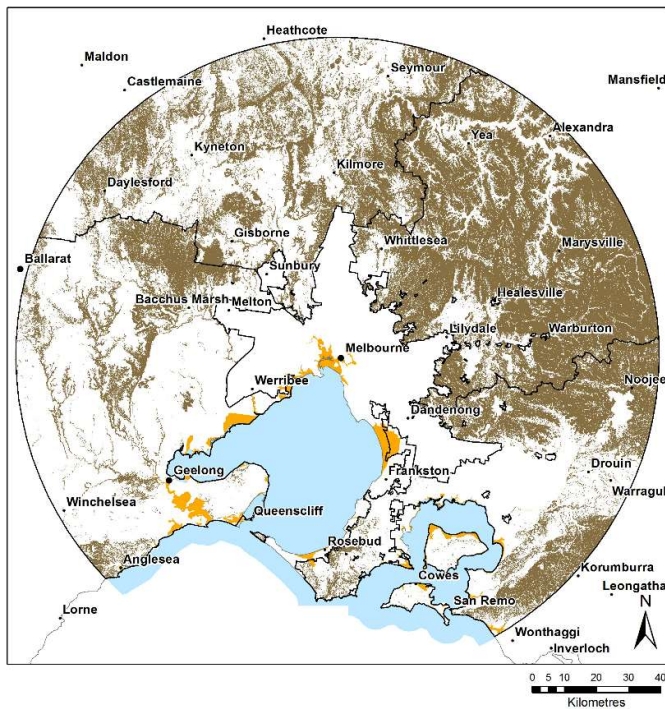
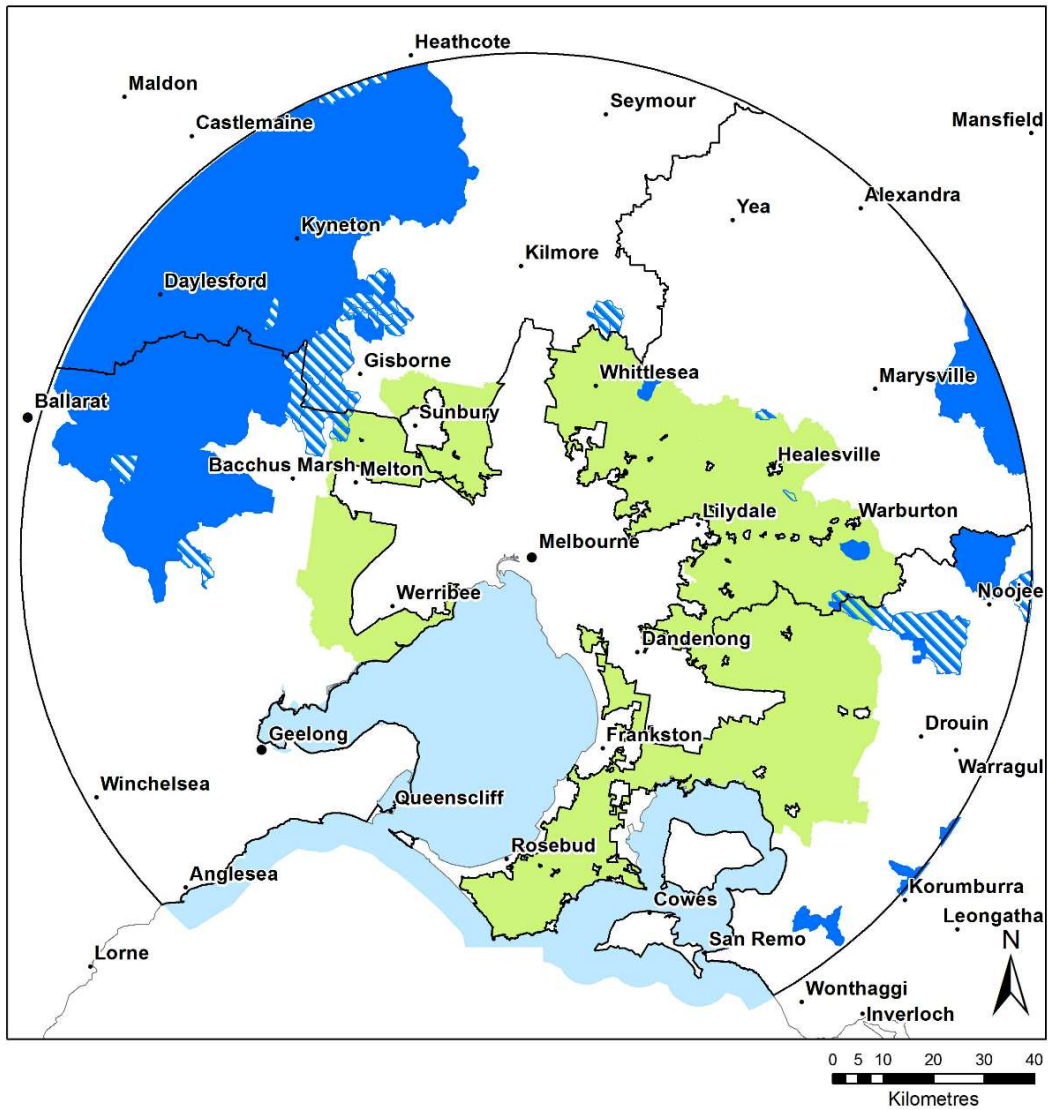


Figure 3. Areas excluded from Land Capability assessment – with potential Coastal Acid Sulfate Soils (CASS) and steep slopes.

Areas excluded from Land Capability Assessment

- Potential CASS
- steep slopes (i.e. >10% slope, apart from landscapes with Ferrosols >20% slope)



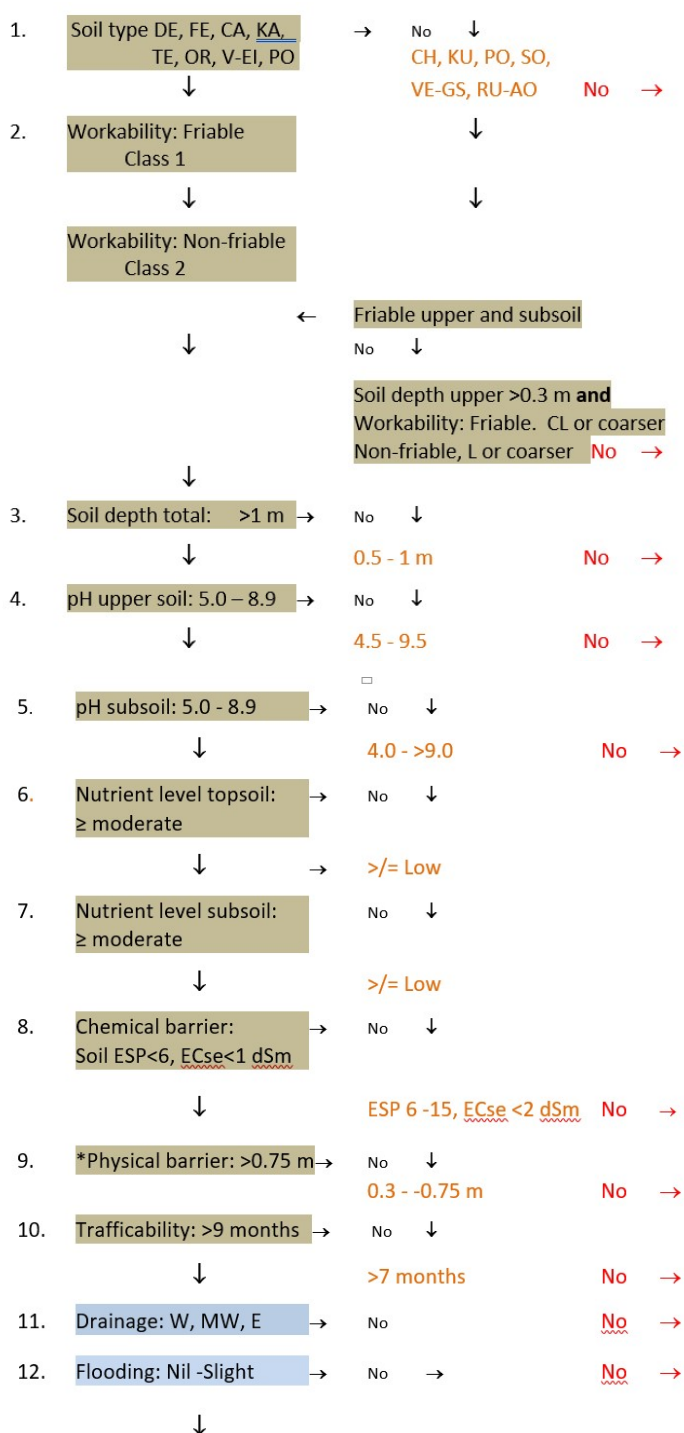
Areas for special consideration

- Declared Water Supply Catchments
- Special Area Plans
- Green Wedges

Figure 4. Areas for special consideration – Declared Water Supply Catchments (including Special Area Plans) and Green Wedges.

2.4 Land capability assessment

Land capability assessment is a method of determining if a land area can sustain a specific use and level of management without causing significant long-term degradation. Soils are a product of their current (and former) environment so are considered first in this assessment, followed by water related factors and then landform. Climatic factors are not explicit apart from rainfall (annual average) given the relatively small geographical area but implicit in the soil types identified. Each of the 1200 mapping units were assessed according to the Schema presented below based on assessment of the dominant soil type in each (noting that some land units may have a combination of sub-dominant and minor soils that are not assessed).



(Factor 1) Soil type affects the degree of restriction for gases and biological activity and here it is assumed that physical features are harder to alter than chemical (nutrient) features. Therefore, texture contrast, or restrictive heavier textured soils (e.g. Sodosols), are identified first as less capable than less restrictive soils with no sudden restrictions down the profile (e.g. Ferrosols, Dermosols).

(Factor 2) Workability and friability are key factors influencing productivity and ease of tillage. Even some well-structured soils may lose their effectiveness under wet conditions, and when combined with compaction forces (e.g. wheel and stock traffic). Strongly structured soils with connected spaces (and pores) have more effective internal drainage (i.e. are more permeable).

The upper soil depth is important for germination and plant development and sufficient depth over a heavier subsoil could be more than adequate for some crops. (Factor 3) A deeper soil profile with fewer restrictions to root and water movement is preferred.

The measurement of acidity/alkalinity via pH is a broad indicator of the nutrient status of the soil and potential toxicities, for both the surface soil (Factor 4) and the subsoil (Factor 5); only the extremes are excluded at this stage before a more direct assessment of nutrient status (Exchangeable Bases and Cation Exchange Capacity) of both the upper soil (Factor 6) and subsoil (Factor 7);

(Factor 8) Some soil chemical properties influence plant growth. A high proportion of exchangeable sodium (i.e. ESP) in the nutrient base can cause plant growth restrictions in terms of both direct effects on roots and indirectly by altering soil structure. High soluble salt content is another possible chemical barrier to plant growth.

13.	Is rainfall >550 mm an av. →	No ↓		
	↓	>400 mm an av.	No →	
14.	Slope: < 20% →	No ↓		
	↓	20-32%	No →	
15.	Rock outcrop: <10% →	No ↓		
	↓	10-20%	No →	
16.	Landslip Hazard: Nil-slight →	No ↓		
	↓	Moderate	No →	
	Class 1 -2	Class 3	Class 4+	

* Examples are some clays with little or no structure and pans (silcrete, calcareous, sesquioxides etc)

(Factor 9) If there are no significant chemical barriers then there is the possibility of physical restrictions such as rock, stone or gravel. High clay content with limited structure could also be restrictive.

(Factor 10) Trafficability is an important feature of the land that influences agronomic operations. This is generally correlated with drainage (Factor 11). Trafficability potential may mean that some positive attributes (e.g. nutrient status) are sacrificed for greater access throughout the year, though issues such as compaction need to be assessed according to the amount of likely traffic/stocking.

Drainage, both in terms of the local landscape (i.e. site drainage and depth to watertable) and down the soil profile (i.e. soil permeability), are important properties influencing the productive potential of land for agriculture.

(Factor 12) Flooding risk/inundation may be an issue in some areas, both in terms of potential and return period. This has often been estimated from landscape and soil features due to lack of specific site data.

Rainfall (Factor 13) is an important factor as a climatic indicator and only low annual average rainfall (i.e. <550 mm) is considered restrictive in this preliminary assessment. This does not mean that supplementary water is not required for some intensive agricultural enterprises in areas with >550 mm rainfall.

High rainfall, in conjunction with certain geological types, may also engender a significant landslip hazard (Factor 14), particularly in combination with steep slopes. Different slope limits (i.e. 20% vs 10%) are used, depending on the likely risk of landslip and erosion hazard in certain susceptible landscapes (e.g. Strzelecki Ranges). Landscapes with Ferrosols as the dominant soil type have a 20% slope cut-off applied.

The final landscape feature for consideration is rock outcrop (Factor 15) which makes cultivation difficult. The main occurrences of rocky outcrops are associated with some granitic, basaltic and acid volcanic landscapes.

Scale and resolution

Due to the resolution of the mapping and natural environment features there may well be components within some land units that are suitable for more intensive uses but are not able to be mapped separately at this stage. To illustrate this concept, Figure 5 provides an example of a description of a soil/landscape mapping unit (1:100 000 scale) south-west of Geelong. The mapped area has five landscape components that are not spatially distinguished, one of which (Component 3), occupying 10% of the mapping unit, has sandy soils that may be potentially suitable for irrigated horticulture. There are many mapped landunits within the study region that have multiple components and more than one soil type. Further on-ground assessment and mapping are required to disaggregate these mapped landscapes to better define specific soil type occurrences.

Component	1	2	3	4	5
Proportion of soil-landscape unit	35%	20%	10%	15%	10%
CLIMATE					
Rainfall (mm)	Annual: 600-650, lowest January (30), highest August (85)				
Temperature (°C)	Annual: 13, lowest July (9), highest February (19)				
Seasonal growth limitations	Temperature: less than 10°C (ev.) June-July Precipitation: less than potential evapotranspiration October-mid April				
GEOLOGY					
Age and lithology	Neogene fluvio-marine sand and minor Recent clay, sand and gravel; Neogene marine marl and Paleogene fluvial sand				
Geomorphology	6.2.4 Plains, rises and low hills of the Sedimentary Western Plains				
LANDUSE					
	Cleared areas: Dairy and beef cattle grazing on mainly improved pastures; cereal cropping; some sand extraction				
TOPOGRAPHY					
Landscape	Gently undulating plain lying between basalt to the north and lateritic plateaux to the south				
Elevation range (m)	40-130				
Local relief (m)	20				
Drainage pattern	Dendritic				
Drainage density (km/km ²)	1.6				
Landform	Gentle rises				Va
Landform element	Crest and upper slope	Middle slope	Crest and slope	Lower slope	
Slope and range (%)	3 (0-11)	4 (1-7)	5 (2-10)	4 (0-7)	1 (0-2)
Slope shape	Convex	Linear	Irregular	Convex	Concave
NATIVE VEGETATION					
Structure	Open forest	Woodland	Low woodland	Woodland	Woodland
Dominant species	<i>E. viminialis</i> , <i>E. ovata</i> , <i>E. pauciflora</i> , <i>Acacia melanoxylon</i>	<i>E. viminialis</i> , <i>E. ovata</i> , <i>Casuarina stricta</i> , <i>C. littoralis</i>	<i>E. viminialis</i> , <i>E. obliqua</i>	<i>E. ovata</i> , <i>E. viminialis</i> , <i>Casuarina stricta</i>	<i>E. camaldulensis</i> , <i>E. viminialis</i> , <i>Acacia melanoxylon</i>
SOIL					
Parent material	Sandy clay	Sandy clay	Siliceous sand	Sandy clay	Sand, silt and clay
Description (Corangamite Soil Group)	Mottled brown, grey, yellow and red texture contrast soils (13)	Yellow-brown sodic texture contrast soils, coarse structure (14)	Grey sand soils (11)	Brown, grey or yellow sodic texture contrast soils (19)	Brown gradational soils (34)
Soil type sites	OTR492, OTR744	OTR006	OTR742	OTR734	OTR414, OTR416, OTR748
Surface texture	Sandy loam	Fine sandy loam	Loamy sand	Sandy loam	Fine sandy loam
Permeability	Moderate	Low	Very high	Moderate	High
Depth (m)	>2	>2	>2	>2	>2
LAND CHARACTERISTICS, POTENTIAL AND LIMITATIONS	Low inherent fertility, phosphorus fixation and leaching of permeable A horizons lead to nutrient decline.	Dispersible subsoils are prone to gully erosion and slumping of road batters.	Low inherent fertility and high permeability lead to nutrient decline. Weakly structured surfaces with low water holding capacity are prone to wind erosion.	Sodic subsoils with high seasonal watertables are prone to soil salting. Dispersible subsoils are prone to gully erosion.	Seasonal saline watertable development leads to soil salting. Rapid surface runoff from adjacent areas leads to scouring and gully erosion. Weakly structured surface soils in poorly drained areas are prone to compaction.



Figure 5. Example of land components within a soil/landscape mapping unit in the Corangamite region.

Other examples of moderate to high capability sub-components of land within land units that would overall be rated as less capable include:

- Soils developed on Tertiary (Neogene) sediments where the surface soils can be sandy in some areas and suitable for horticulture, depending on the depth of surface horizons above the denser and more clayey subsoil. Specific occurrences of this situation are likely on the Mornington and Bellarine Peninsulas, and to the west of Geelong. For this study, in terms of soil properties, the determination of Land Capability is based on the dominant soil type in each mapping unit so that minor soils are not factored in. A soil type may have variability in some key features (e.g. depth of surface horizons), which implies local variation in behaviour, but a standard description can only be used in broadscale capability assessments. Another example of component areas of higher potential on basaltic terrain include areas associated with eruption points (lower slopes) and intervening areas on stony terrain, for example in the Mt Kororoit area. Soil types with fewer rocks that occur on lower slopes are more suitable but then merge into less suitable texture contrast soils on the plains. Plate 3 shows differences in soil type and associated land uses at this local scale that are not possible to separate out in a broadscale land capability assessment.
- Granitic landscapes with gentle lower slopes, where erosion potential can be controlled, and with lighter (i.e. sandier) textured surface horizons that are of sufficient depth for more intensive use. An example, outside the study area, is the Harcourt horticultural zone that is used extensively for orchards.



Plate 3. Different soil types and associated land uses on rises and lower slopes of Mt Kororoit.

2.5 Mapping current intensive soil-based agricultural land use

Existing data was sourced from Victorian Land Use Information System (VLUIS). Extensive additional image interpretation and ground-based assessment has also been carried out in this project to map areas not identified in the VLUIS dataset. This has identified extensive areas not previously mapped and provides a new and unique mapping product. Land use has not been mapped for areas within the Urban Growth Boundary (UGB).

2.6 Groundwater assessment

Regarding agricultural land capability, groundwater can be considered both a resource and a threat. To be a resource, it must be present under the land in a suitable aquifer at an economically accessible depth; be extractable at a useful rate and of be of suitable quality (mostly salinity related, but other pollutants can also be a limiting factor). A more modern water resource aspect now includes the potential for a groundwater supply to be enhanced through aquifer recharge and recovery (thereby using aquifers as a drought resistant water storage medium). However, such opportunities can only be acted upon if a suitable supply of recharge water is available, such as harvested rainwater or high quality treated wastewater.

Where groundwater conditions may pose a threat, there are two main considerations:

- Groundwater being too close to surface or actively discharging (e.g. the watertable is within two metres of the land surface, i.e. areas close to sea level, or where excess recharge from irrigation has created a high watertable, or in spring discharge or dryland salinity discharge situations). A high watertable can cause soil waterlogging, anoxic conditions, altered pH levels and structural degradation. If the near surface groundwater also contains dissolved salts, evapotranspiration can lead to concentration of those salts in the rootzone, loss of plant productivity, soil chemical degradation, erosion, salt wash-off and water quality degradation.
- In circumstances where a high watertable might be a land-use limiting factor, the hydrogeology of a site can also be an important consideration for development of management or amelioration options; for example, shallow groundwater pumping can provide a mechanism to control high watertables and manage the salinity threat.

Method for Groundwater Assessment

This hydrogeology assessment was conducted following the steps outlined below:

- Gathering of hydrogeology information for the study area, including mapping of geology, Groundwater Flow Systems (GFS), licensed bore data, Groundwater Management Areas (GMAs), salinity discharge areas. Reference was also made to the Port Phillip and Westernport Groundwater Atlas (Sothorn Rural Water, 2014) and relevant groundwater resource management planning documents (e.g. SRW 2014, 2016, 2017 and GMW 2012, 2013).
- Analysis of the available water resource from recent usage data to describe how the groundwater resource enhances the production value of the higher rated agricultural land.

- Processing mapping information to a suitable format for use across the study area, for example by stitching together the disparate GFS mapping for the four adjoining catchments and standardising the flow system categories.
- Deciding the criteria upon which to base an implied land capability from the hydrogeology information.
- For land within the 100 km radius study area, correlating the Agricultural Land Capability *Classes 1, 2 and 3* with hydrogeology information to categorise land as having either a resource or threat implication (or both). Some limited consideration of potential surface water supply has also been included where it may have implications for future Aquifer Storage and Recovery (ASR) opportunities.

3. RESULTS AND DISCUSSION

3.1 Land Capability mapping

Mapping an area of land can be a complex task as many differences arise due to interactions between climate, geology and topography. While it is possible to measure and determine some of the land characteristics such as slope, rock outcrop, and soil type, other characteristics such as site drainage, and permeability are less easily determined. The main objective of land resource mapping is to identify areas of land that are uniform with respect to the land characteristics which affect land use. These areas of land have a similar land use capability and are likely to respond in a similar way to management. Figure 6 shows the Land Capability map with the following classes mapped:

- **Class 1:** Land that is inherently capable for intensive soil-based agriculture, particularly horticulture. This class includes landscapes with Ferrosols on more gentle slopes and some alluvial areas. The access to a constant water supply will generally improve the capability of the land. Some land is included in this category due to improved land management (e.g. drainage, water access). Land management limitations are nil to slight. *Class 1* land covers around 3% of the total land area in the study area.
- **Class 2:** Land that is inherently capable for intensive soil-based agriculture, including horticulture and dairying. This class includes Ferrosols on steeper terrain (i.e. slopes >10%) and former swamp landscapes that have been extensively drained and have organic rich soils that also require adequate site drainage. Land management limitations are slight. *Class 2* land covers around 2% of the total land in the study area.
- **Class 3:** Land that is inherently capable for soil-based agriculture at moderate to high intensity. The potential/capability may vary (e.g. according to slope, inherent fertility and drainage) but is often realised with access to a constant water supply. Many landscapes with deeper sandy soils are represented here – which are highly suited to horticulture once land-forming, drainage, fertilisers and irrigation is provided. Suitable landscapes with more favourable texture-contrast soils (e.g. deeper surface horizons, relatively friable and stable upper subsoils) are also included. Land management limitations are slight to moderate for intensive use. *Class 3* land covers around 9% of the total land in the study area.
- **Class 4:** Land that is not as inherently capable for intensive soil-based agriculture. Extensive agriculture (including broadacre cropping with suitable land management practices) and non-soil utilisation activities are often most appropriate, and more intensive grazing is possible in some higher rainfall areas or where consistent water supplies are available. Due to mapping resolution, some minor exclusion areas (i.e. *Class 5*) can be present where land attributes (e.g. slope) vary locally. Land management limitations are high to very high for intensive use. There are also likely to be some areas of land within this Class that may have higher capability (e.g. suitable terrain with soils that have deep sandy surface horizons) but that are not able to be identified at this stage due to the broad scale of soil/landscape mapping available across much of the study area. *Class 4* land covers 36% of the total land in the study area.
- **Class 5:** Land that is excluded from this study. This includes Public Land, areas within the Urban Growth Boundary (UGB), steep terrain (i.e. slopes >20% in landscapes with Ferrosols as dominant soils and landscapes with slopes >10% elsewhere) and areas with potential Coastal Acid Sulfate Soils (CASS). *Class 5* land covers around 50% of the total land in the study area.

It should be noted that Land Capability analysis is based on available soil and landscape mapping and data, which varies in scale and quality across the study area. It provides an indication of likely capability based on existing information and provides a useful basis for further finer-scale assessments. A detailed on-site assessment of the soil and landscape should be carried out prior to any proposed development taking place.

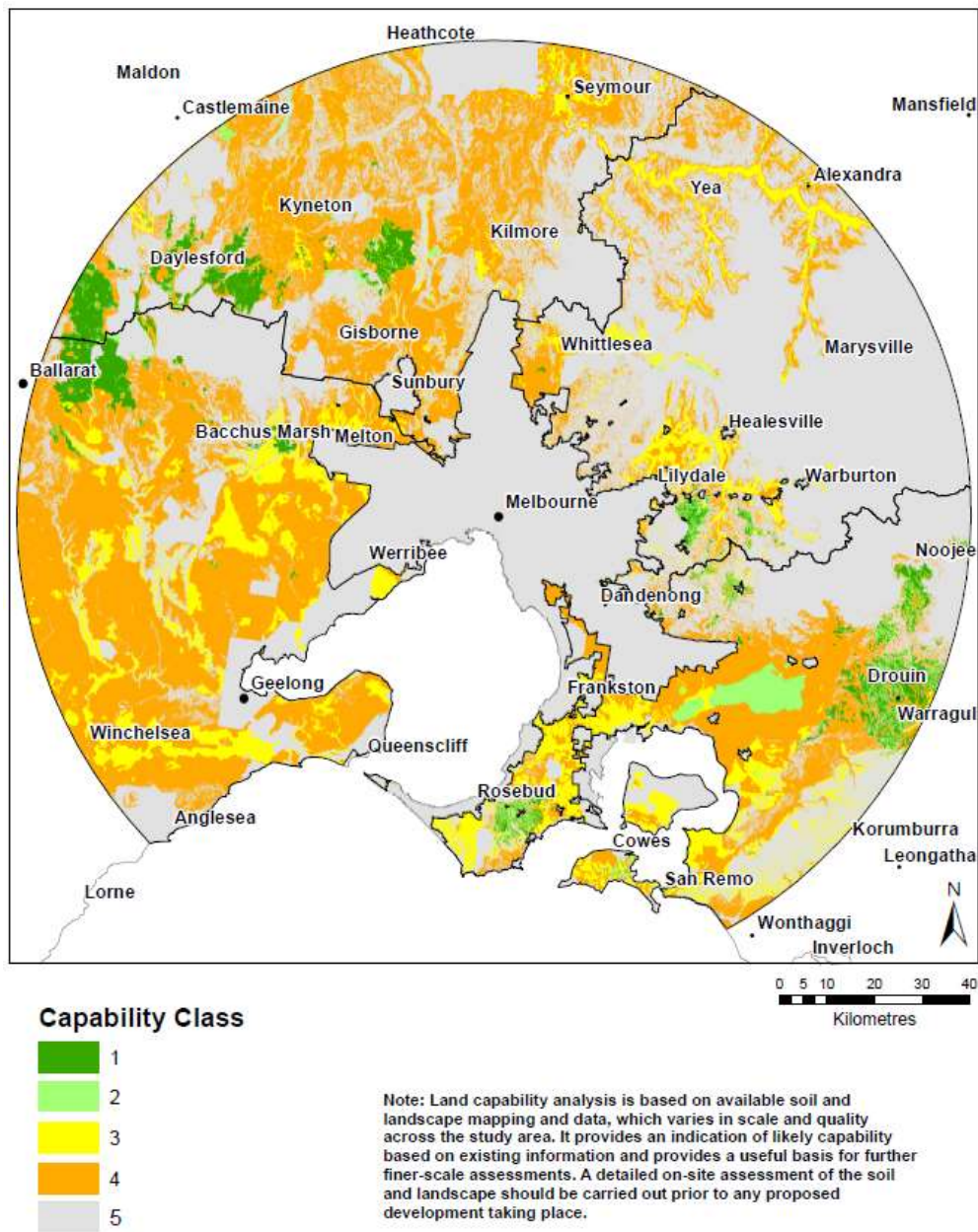


Figure 6. Land capability map for Melbourne's Green Wedge and Peri-urban areas.

3.2 Brief description of some key Land Capability Class 1 and 2 landscapes

Landscapes within Land Capability Classes 1 and 2 vary generally from alluvial plains (floodplains and river terraces) to low hills. Drainage is an important attribute that needs to be tempered by nutrient holding capacity, workability, soil structural stability and erosion potential.

3.2.1 Alluvial terraces in Keilor region

Alluvial areas in general can often be Land Capability Class 1 or 2 depending on soil type and the trade-off between drainage and flooding frequency. Traditionally these soils have been considered some of the most fertile areas for cultivation. The degree of variation such as prior streams and back-plains can increase the variability that land managers need to deal with. Alluvial terraces such as in the Keilor area, although often small in areal extent, are a prime example of soils more suited to intense cultivation (as shown in Plate 4). This applies slightly less to the Werribee Delta where more difficult to manage sodic texture-contrast soils occur.



Plate 4. Horticulture in small alluvial valley near Keilor (Photo: Mark Imhof)

3.2.2 Rolling low hills (Older Volcanics) in West Gippsland and Mornington Peninsula

The rolling low hills in West Gippsland (particularly around Warragul-Drouin and Neerim South areas, as shown in Plate 5) are widely used for dairy grazing and cropping (e.g. potatoes, cut flowers). Ferrosols are the dominant soil type in these areas. They are stable, well drained soils in general and can therefore tolerate cultivation on steeper slopes dependent on management. The degree of landscape dissection will also influence management, with more highly dissected areas (rolling hills) limiting the extent of continuous

crop
ping



Plate 5. Dairy grazing and cropping at Neerim South in West Gippsland (Photo: Mark Imhof)

The rolling low hills in the Red Hill region on the Mornington Peninsula have also developed on *Older Volcanics*. The dominant soil is Ferrosols, occupying just over half of the mapped area. These soils are highly prized for berry crops and orchards, particularly apples. Where slopes are favourable, more land is being planted with vines. After vines are well established on these soils no further supplementary water is often required and plant vigour needs to be controlled. Texture contrast soils also occur within this area but are not able to be separated at this mapping scale.

3.2.3 Hills in Dandenong and Yarra Ranges region with friable and well drained soils

The terrain on *Older Volcanics* geology has been identified and used extensively by post European settlement for intensive agriculture, particularly in the Silvan area and surrounds (e.g. Plate 6). The soils are easily workable and well drained. The rolling terrain is both aesthetically pleasing and productive with berry production as well as market gardening, orchards and flower production championed by earlier Dutch and German settlers. However, even these relatively stable soils are prone to degradation, particularly compaction, and erosion. Exposure to extreme climatic conditions under constant cultivation led to significant erosion in the 1980s.



Plate 6. Cropping in the Dandenong Ranges

Similar soils occur on the acid volcanic rocks, such as the main Dandenong Range, but are not as inherently fertile. As a generalisation the same can be said for the undulating plateau soils at Kinglake to Melbourne's north west. Here the soils are red, friable and well drained but not as fertile as the Silvan area, being based on Palaeozoic sediments. There is a history of potato growing in the Toolangi area, with berries are now commonly grown (Plate 7). The Dandenong and Yarra Ranges region is subject to climatic conditions that define the optimum crops. The Kinglake area, for example, is at relatively higher elevation, and therefore cooler, which can result in a reduced growing season for some crops, but act as a viable niche for others.



Plate 7. Strawberry cropping on Red Ferrosols at Toolangi (Photo: Mark Imhof)

3.2.4 Volcanic plains and rises in the Ballarat region

The soils on undulating plains and rises in the Ballarat region have developed on Quaternary ('Newer') Volcanics and Ferrosols are typically the dominant soil type. Ferrosols in this region are generally not as deep compared to those on 'Older Volcanics' in the eastern part of Melbourne's peri-urban zone.

Slope and depth to rock are key to an area being classified as either *Class 1* or *2*. The degree of landscape dissection will influence management, with more highly dissected areas (rolling hills) limiting the extent of continuous cropping. Much of the area to the east and north east of Ballarat has gentler slopes that have fewer terrain restrictions, although they can be interrupted by minor low eruption points. Plates 8 and 9 are examples of landscapes in this area. These soils also overlie well developed groundwater resources of the Loddon Highlands and Bungaree Groundwater Management Areas.



Plate 8. Potato cropping on Red Ferrosols east of Ballarat (Photo: Mark Imhof)



Plate 9. Potato cropping and grazing on Red Ferrosols east of Ballarat (Photo: Mark Imhof)

3.2.5 Former swamp deposits in the Koo-Wee-Rup area

A range of organic rich soils have developed on the former swamp areas in the Koo-Wee-Rup district (Plates 10 and 11). These soils have been highly sought after for market gardening (especially asparagus) as they are high in organic matter and relatively friable. Around 40% or greater of the area of organic rich soils in this region (as shown in Figure 10) currently support horticulture. The area has been extensively drained since the 19th Century, making this a viable cropping region. Since drainage, much peat has disappeared through shrinkage, consolidation, burning and blowing. The more clayey soils are also prone to compaction due to excessive tillage or use of heavy machinery when the soil is too moist. Over 380 groundwater licenses are held in the Koo-Wee-Rup Groundwater Management Area. This 23,800 ML irrigation water resource supplies

many of the market gardens and offers potential to be enhanced with integrated water management systems that could be incorporated into urban development areas to the north.



Plate 10. Vegetable cropping near Dalmore (Photo: Mark Imhof)



Plate 11. Asparagus cropping near Iona (Photo: Mark Imhof)

3.3 Brief description of some key Land Capability Class 3 landscapes

3.3.1 Sand plains and rises in the Port Phillip Bay region

There is a range of sandy soils developed on aeolian deposits in the Port Phillip Bay region. These soils are inherently infertile and have a low water holding capacity. They are, however, well drained and easily workable, so with land-forming, irrigation, fertilisers and additional organic matter they can become highly productive. A key attraction of these soils is that they can be cultivated over most of the year. This capability makes these soils the most sought after for vegetable cropping. Plate 12 is an example of a sandy soil landscape near Clyde (which is now within the Urban Growth Boundary and currently being developed for urban living – see same area in Plate 2).



Plate 12. Vegetable cropping near Clyde (Photo: Mark Imhof)

3.3.2 Volcanic plains west of Melbourne

Many of the soils west of Melbourne that have developed on basalt are texture contrast with variable amounts of rock and depth to bedrock. Where much of the land has not been cleared of stone, the soils are used for sheep and cattle grazing on unimproved pastures. Less stony areas (including those that have been 'stone picked') have been cropped on a rotational basis with grazing. Existing soil/landscape mapping does not allow many of the less stony soils to be separated out enough to differentiate potential *Class 3* areas from *Class 4*. Some areas in the Balliang district (e.g. Plate 13) are used for cropping, but usually require careful management, including application of gypsum to deal with sodicity. The move to minimum tillage has been beneficial for managing these soil types. Areas around Melton with negligible rock have also been used for broadacre cropping, but some of these areas are now within the Urban Growth Boundary (e.g. Plate 14)



Plate 13. Cereal cropping near Balliang – note gypsum piles in background (Photo: Mark Imhof)



Plate 14. Broadacre cropping at Leakes Road Truganina in the early 2000's. This area is now within the Urban Growth Boundary.

3.3.3 Alluvial plains at Werribee South

The alluvial plains at Werribee South have been used extensively for vegetable cropping (e.g. Plate 15). Soils developed on alluvial deposits in the 'Werribee Delta' are generally texture-contrast soils with sodic subsoils (Red Sodosols). An example soil profile at Werribee is shown in Plate 16. The surface soils are generally between 20 - 35 cm deep and are usually reasonably friable brown to greyish brown silty to fine sandy clay loams and fine sandy loams that are slightly acidic. When dry, these surface soils become hardsetting. The subsoils are generally dark brown, dark reddish brown, or dark greyish brown medium clays which are mainly sodic. In many parts of Victoria, sodic texture-contrast soils are not considered ideal for intensive cropping. However, due to their relatively deep surface soils (overlying denser sodic clays) soils, and availability of surface water and groundwater resources of the Deutgam GMA, these soils are intensively used but do require more careful management.



Plate 15. Vegetable cropping on older alluvial plains at Werribee.



Plate 16. Texture-contrast soil developed on older alluvial plain near Werribee.

3.4 Distribution of current agricultural land uses

A new map, as shown in Figure 7, has been developed to show current soil-based agricultural land uses, particularly vineyards, orchards, market gardens, dairy and general cropping. Areas of predominantly non-dairy grazing have not been mapped. This map builds on data obtained from the Victorian Land Use Information System (VLUIS) together with significant new mapping based on recent field observations undertaken as part of this study. Additional mapping would be of value to better define dairy areas in the western part of the peri-urban zone and broadacre cropping, particularly in the Inverleigh and Balliang areas. There are also likely to be many smaller areas of intensive agriculture that remain unmapped.

The map highlights the extensive dairy production in the south-eastern part of the peri-urban area. Market gardening is a major land use in the Koo-Wee-Rup area (based on organic rich soils), in the Dandenong Ranges (based on Ferrosols), around Tyabb and Cranbourne (on sandy soils) and south of Werribee (on red texture contrast soils). Potato cropping is the dominant land use to the north-east of Ballarat and is largely based on Ferrosols. The potato cropping area accounts for approximately 20% of the total area of Ferrosols in the study area. Viticulture is dominant in the Yarra Valley and southern Mornington Peninsula areas (based on a range of soil types). General cropping (mainly cereals) occurs mainly in the south-western part of the Peri-urban zone, particularly in the Balliang and Inverleigh areas.

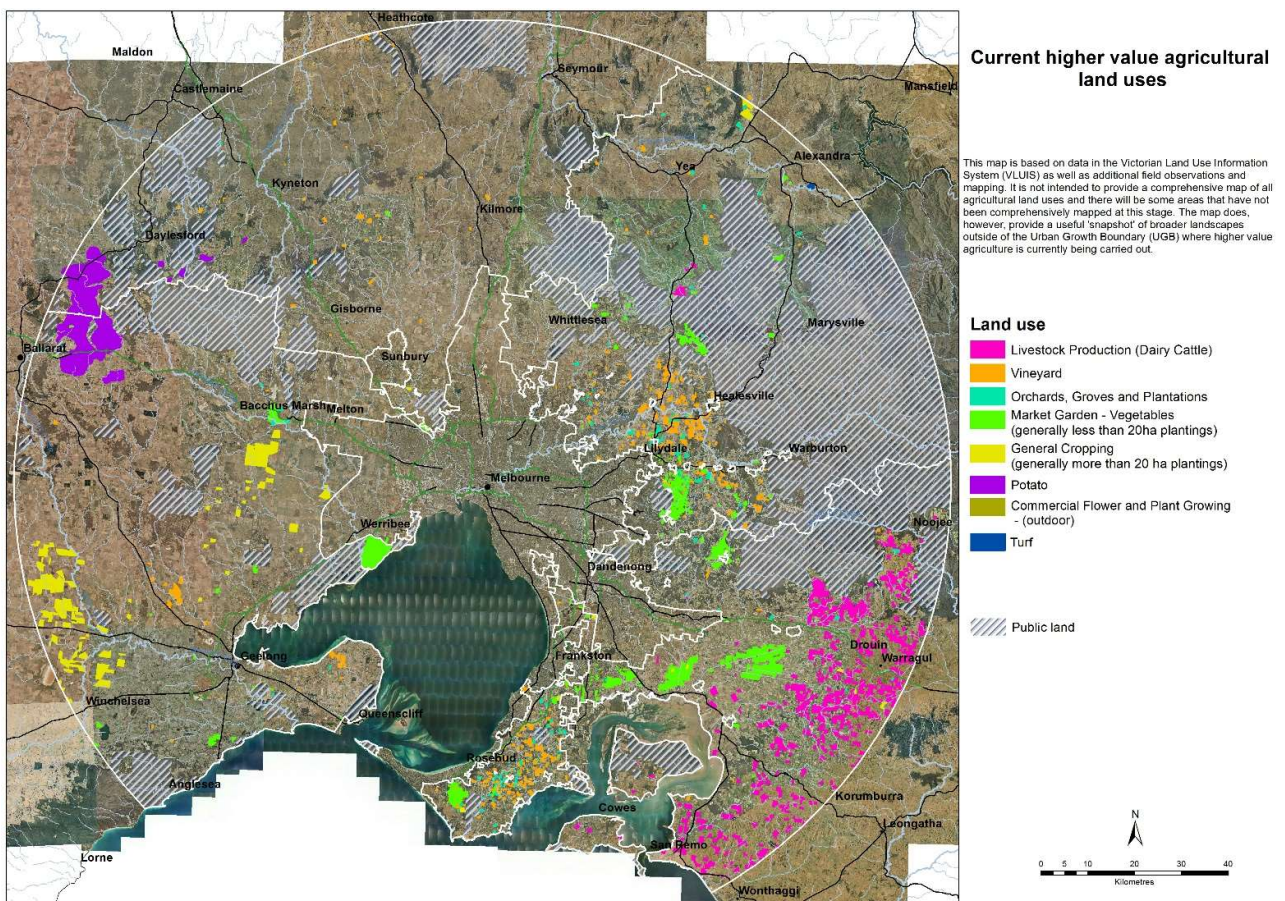


Figure 7. Current intensive agriculture land uses, with a focus on dairy, horticulture, viticulture and general cropping.

3.5 Description and mapping of some key soil types suited to intensive agriculture

New maps have been developed that show land units with dominant soil types that are particularly favorable for intensive horticulture. These include Ferrosols, sandy soils and friable organic rich clay soils.

3.5.1. Ferrosols

Ferrosols (formerly known as 'krasnozems') are deep, well-drained and friable red soils developed on basalt. Areas with Ferrosols as the dominant soil type are shown in Figure 8. The map shows Ferrosols developed on *Older Volcanics* (east of Melbourne) and *Newer Volcanics* (to the west of Melbourne). Ferrosols are commonly associated with rolling hills in the Warragul, Mornington Peninsula and Dandenong and Yarra Ranges regions and on rises to the east of Ballarat. They support higher value production such as dairying (mainly in West Gippsland) and horticulture (e.g. market gardens, orchards, potatoes, cut flowers and berries).

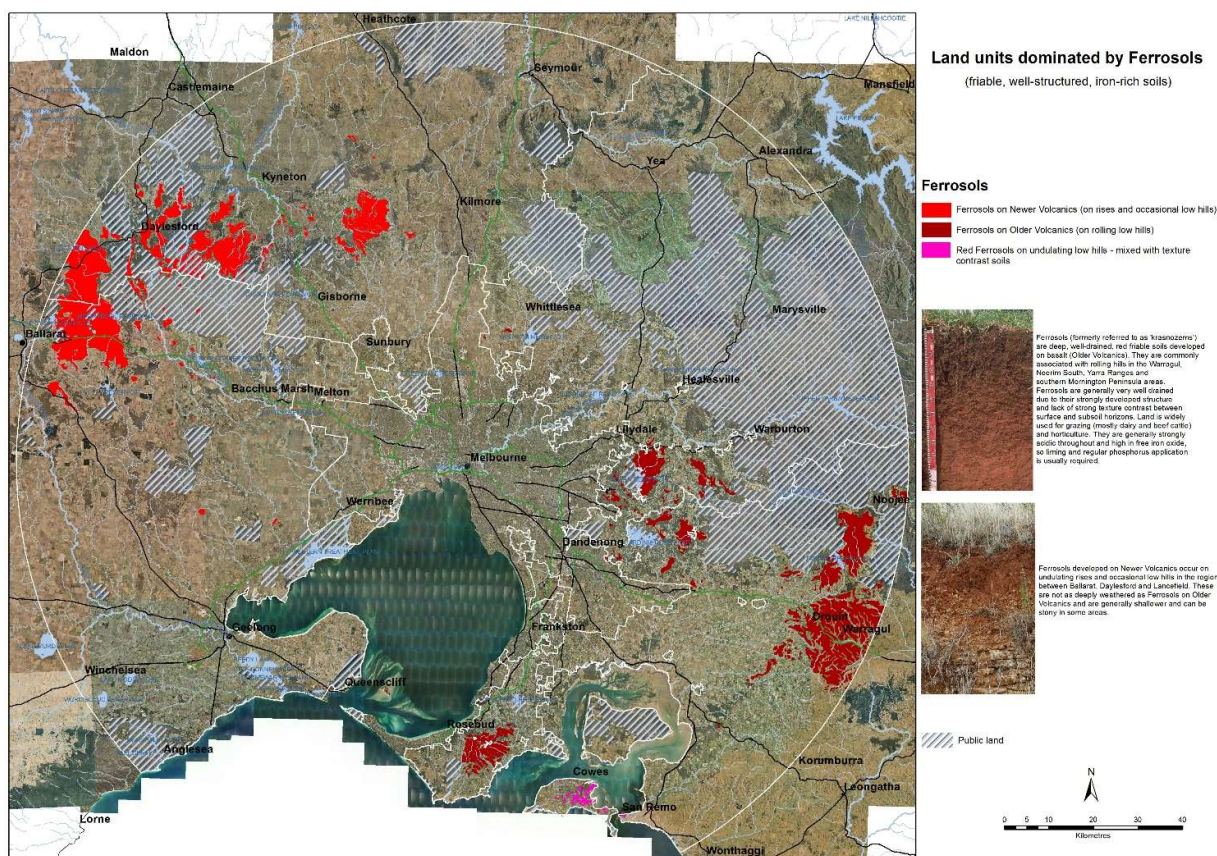


Figure 8. Land units with Ferrosols as a dominant soil type.

Example profiles are shown in Plate 17. Ferrosols are well structured and friable soils but are often strongly acidic and high in free iron oxide, so liming and regular phosphorus application is usually required. Ferrosols developed on *Older Volcanics* are usually deeply weathered and generally strongly acidic throughout. Ferrosols developed on *Newer Volcanics* occur on undulating rises and occasional low hills in the region between Ballarat, Daylesford and Lancefield. These are not as deeply weathered and are generally shallower and can be stony in some areas.

Under continual cropping, soil structure and fertility can decline significantly. Being acidic they generally require lime for and fertilisers for intensive cropping. Ferrosols have high levels of free iron oxide which gives them a high degree of structural stability. Red Ferrosols have a high pH buffering capacity (i.e. require a larger lime application to raise soil pH). Over-liming, however, may result in some micronutrient deficiencies and

may result in reduced aggregate stability. As they are often strongly acid (at least in the upper soil profile) the level of exchangeable aluminium can become high which will restrict the growth of aluminium-sensitive species. Due to high free iron oxide contents these soils tend to "fix" phosphorus which makes it less available to plants. Regular phosphorus application will assist in overcoming such a deficiency. Soil compaction from trafficking, over-stocking or cultivation can lead to reduced water infiltration and retention as well as an increase in soil strength (resulting in mechanical resistance to roots) and cloddiness. These soils are more prone to compaction when the soil is wetter than the plastic limit. Ideally, tillage, trafficking and stocking should occur when the soil is drier than the plastic limit (at least within the top 40 cm from the surface or to the depth of cultivation). Compaction on soils such as these can be more serious than on cracking clay soils that tend to self-repair due to their strong shrink-swell capacity. Red Ferrosols generally have high organic matter levels, which enhances soil fertility and aggregate stability. When intensively cropped, organic matter levels can significantly decline and result in some structural degradation and fertility decline. Studies have shown that organic matter is an important source of nitrogen, phosphorus and sulphur in such soils. Organic matter levels can be improved by utilising green manure crops, crop residue retention, minimal cultivation and pasture rotations. Management practices which result in increased organic matter levels include: minimum tillage; growing green manure crops (e.g. annual ryegrass, sorghum, oats, lupins); incorporating pasture phases in crop rotations, and retaining and incorporating crop residues (Cotching 1995).



Plate 17. Example Ferrosol soil profiles; on *Older Volcanics* in West Gippsland (left) and *Newer Volcanics* near Ballarat (right).

3.5.2. Sandy soils

A range of sandy soils, as shown in Plate 18, have been mapped for this study (as shown in Figure 9). Podosols are the most widespread and are formed on early Pleistocene age sands which generally occur as low dunefields and undulating sand plains. They typically have a dark grey sandy surface, becoming bleached by about 30 cm depth. Dark brown and yellow brown cemented sands (termed 'coffee rock') usually occur by about 1 metre depth. These soils are inherently of low fertility and retain little water due to their sandy texture. However, with irrigation, fertilizers and additional organic matter they can become highly productive, particularly for market gardening. The main attraction of these soils is that they can be cultivated over most of the year and often two or more crops may be grown annually. In some areas the coffee rock layer and deeper clay layers may impede the free downward movement of water. Subsurface drainage is normally required for vegetable production over the wetter months.

Deep sands also occur in the Boneo region of the Mornington Peninsula and may not always contain significant amounts of coffee rock. Calcareous sands are most common in the southern part of the Mornington Peninsula.



Plate 18. A range of sandy soil profiles: from left to right, Podsol near Cranbourne, deep sand at Boneo and deep sand over clay at Clyde.

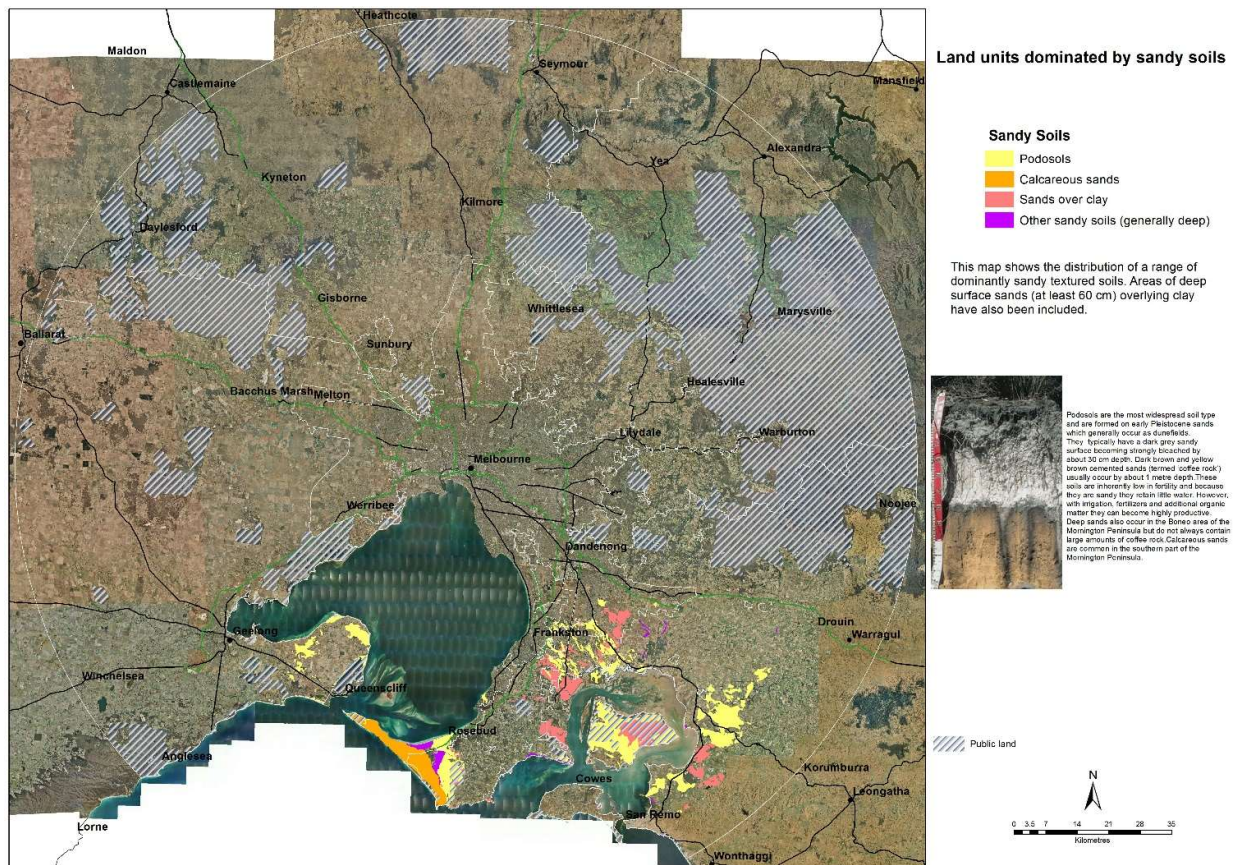


Figure 9. Land units with sandy soils as dominant soil types.

3.5.3. Organic rich soils

Organic rich soils are commonly associated with former swamp deposits in the Koo-Wee-Rup region. They range from dark self-mulching cracking clay soils to dark organic rich clay loams to light clays (e.g. Plate 19). Many of these soils have varying amounts of peaty material at depth. They are usually strongly acidic, can be prone to compaction and require internal drainage but have a long history of intensive vegetable production when managed effectively. The location of these soils in the Koo-Wee-Rup region is shown in Figure 10.



Plate 19. Friable, organic rich soils used for horticulture in the Koo-Wee-Rup area (Photo: Mark Imhof)

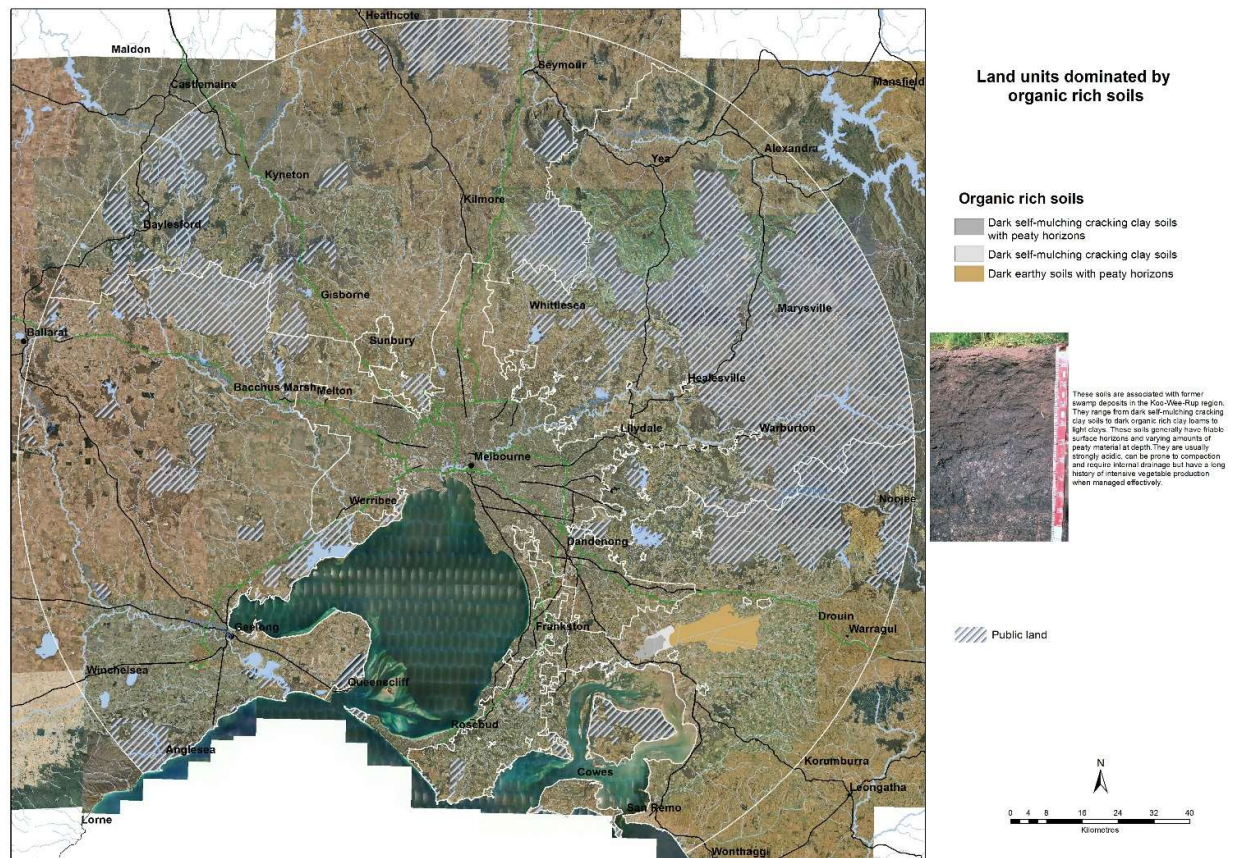


Figure 10. Land units with friable organic rich soils as dominant soil types.

3.6 Groundwater resources and management

3.6.1 Availability of groundwater for agriculture

- Within the 100 km radius of Melbourne study area, groundwater is licensed by Southern Rural Water (SRW) south of the divide and by Goulburn Murray Water (GMW) to the north. Licensed entitlement is in the order of 60,000 ML, and agriculture is the dominant user of the licensed holdings. The SRW Port Phillip and Westernport Groundwater Atlas (2014) states that Agribusiness User Groups use groundwater for intensive commercial, agricultural and horticultural purposes (including irrigating vegetables or pasture, dairy wash, water bottling and aquaculture). It occurs mainly in the areas south-east of Melbourne and in smaller pockets around Bacchus Marsh, Lancefield, Werribee and Wandin. Figure 11 shows a substantial part of the study area as mapped in the Atlas. There are approximately 1300 licensed bores, of which the majority are used for agricultural irrigation. There are also a larger number of Domestic and Stock (D&S) bores, that are considered to use less than 1.3 ML per year.

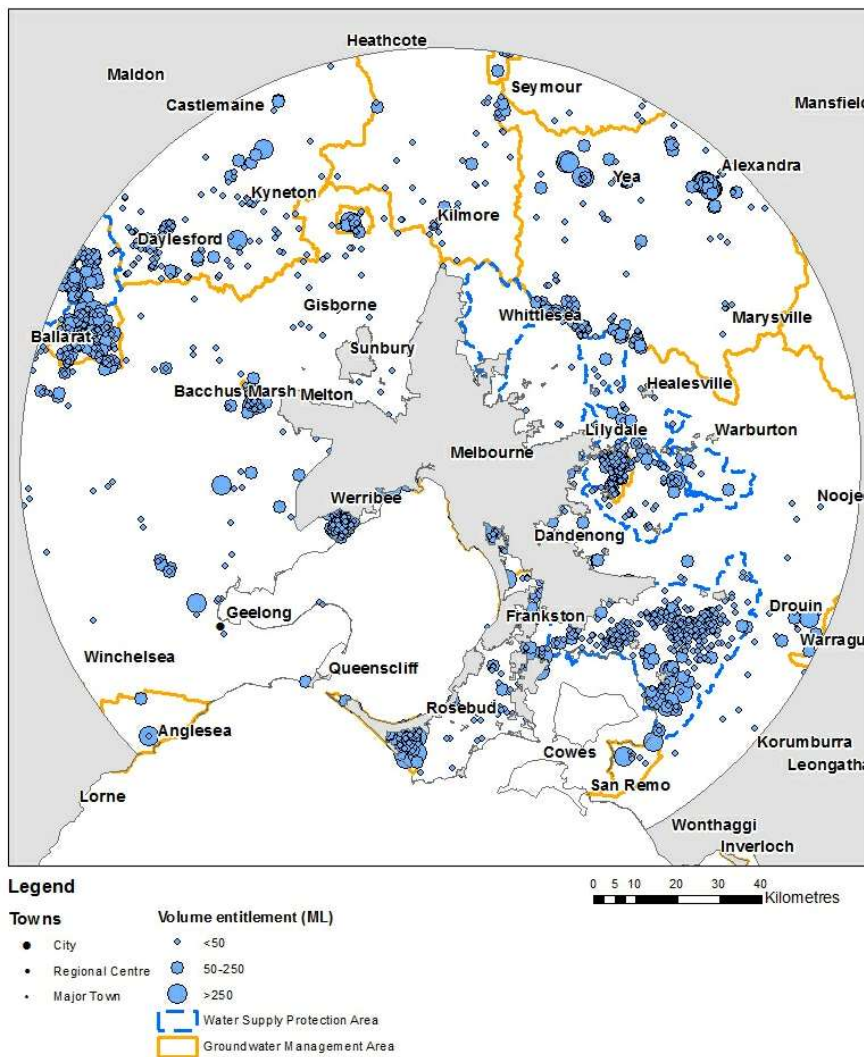


Figure 11. Groundwater volume entitlement (ML), Groundwater Management Areas (GMAs) and Water Supply Protection Areas (WSPAs).

The value of the groundwater contribution to agri-business production for the Port Phillip and Westernport catchments was estimated at \$23.5 million in 2011 (SRW, 2014, based on RMCG, 2011). The drought security contribution of groundwater is much harder to economically quantify.

Aquifers that yield irrigation quantities of low salinity water have been intensively developed to support irrigated agriculture in a few key locations in the study area. Sometimes it is the sole water supply, and sometimes it is used in conjunction with surface water supply. Where agricultural land has access to groundwater, the land can be particularly valuable because the groundwater supply provides a high level of drought security. Where groundwater has been heavily developed and the need to equitably manage the water resource has arisen, the two rural water authorities have worked with the users to apply Groundwater Management Area (GMA) provisions and developed Water Supply Protection Area (WSPA) Plans.

Key concentrations of agricultural groundwater usage in declared GMAs are found at: Werribee (Deutgam) Bacchus Marsh (Parwan and Merrimu) Lancefield, Moorabbin, Frankston east, Wandin Yallock, Nepean (Mornington Peninsula) Koo-Wee-Rup, Corinella and East Ballarat (Bungaree). To the north of the divide, the study area covers parts of the Loddon Highlands (Newlyn area), Kinglake and the Upper Goulburn GMA. Central Victorian Mineral Springs and West Goulburn GMAs also are partly covered by the study area, but the significance of irrigation use in these is low.

Figure 12 (below) shows the location of licensed bores and the boundaries of GMAs and WSPAs within the study area. Table 1 (further below) lists volumetric data pertaining to each GMA that is fully or partially contained within it. Note that several northern GMAs only partially intersect the study area, so the volumetric data presented in Table 1 is not precise. Groundwater irrigated agriculture north of the Great Dividing Range comprises only a small proportion of the total volume used in the study area.

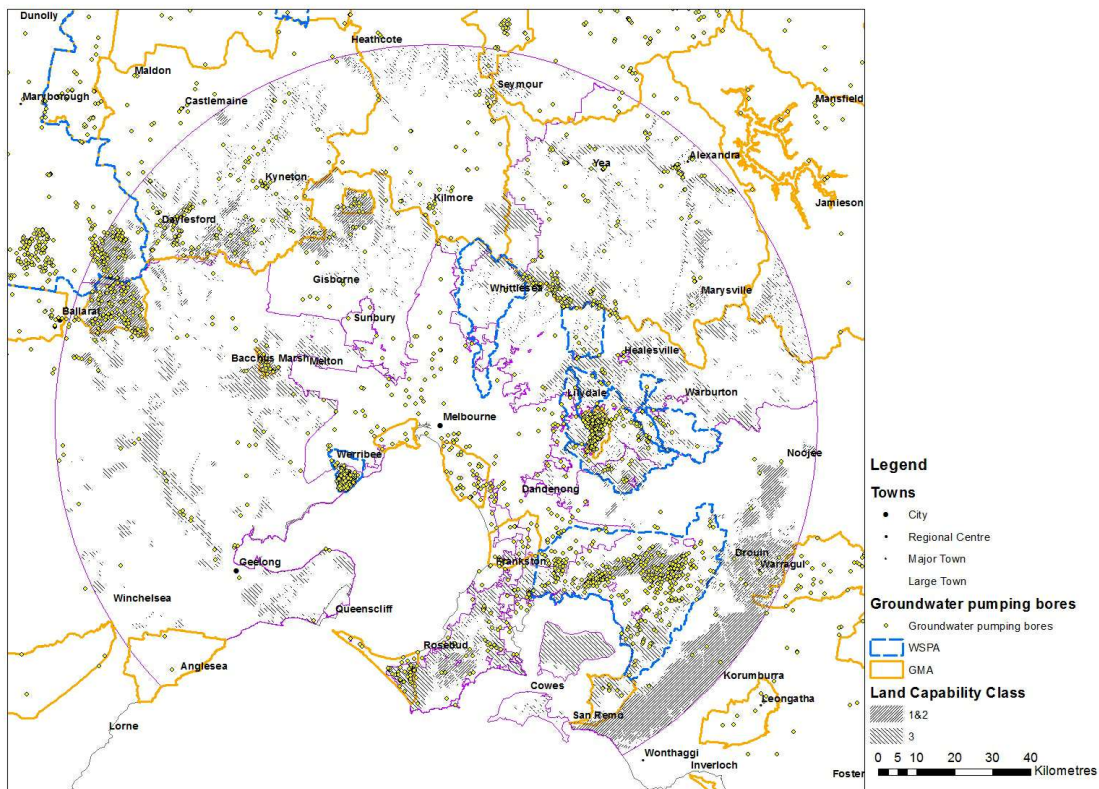


Figure 12. Study area mapped with licensed bore locations (both SRW and GMW jurisdictions) with GMAs (green) and WSPAs (blue shading) against Land Capability Classes 1&2 and 3.

Table 1. Descriptive data for Groundwater Management Areas (GMAs) within the Melbourne peri-urban study area.

GMA NAME	GMU Type	RWA	Aquifer Type	Allocation Limit (ML)	PCV	Formation name	Type	Licensed Entitlement	# licences	Metered Vol (ML) 2009	Metered Vol (ML) 2015
Alexandra ^{*1}	GMA	GMW	Unconfined	1,937	PCV	Not Listed	Bedrock	1,714	10	238	
Kinglake ^{*1}	GMA	GMW	Unconfined	2,015	PCV	Humevale Siltstone	Bedrock	1,864	56	202	
Loddon Highlands	WSPA	GMW	Unconfined and Confined	20,521	PCV	Newer Volcanics and	Non-Bedrock	20,491	180	5,066	11,659
Bungaree	WSPA	SRW	Unconfined and Confined	5,321	PCV	Newer Volcanics	Non-Bedrock	5,333	104	4,383	2,215
Corinella	GMA	SRW	Unconfined and Confined	2,550	PCV	Childers Formation	Non-Bedrock	662	14	43	49
Cut Paw Paw	GMA	SRW	Confined	3,650	PCV	Werribee Formation	Non-Bedrock	514	4	68	246
Deutgam	WSPA	SRW	Unconfined	5,100	PCV	Quat. Alluvials	Non-Bedrock	5,082	147	24	1,405
Frankston	GMA	SRW	Unconfined and Confined	3,200	PCV	Brighton Group	Non-Bedrock	1,671	29	211	50
Koo-Wee-Rup	WSPA	SRW	Unconfined and Confined	12,915	PCV	Western Port Group	Non-Bedrock	12,826	386	5,036	3,661
Lancefield	GMA	SRW	Unconfined	1,485	PCV	Newer Volcanics and	Non-Bedrock	1,390	15	429	243
Merrimu	GMA	SRW	Unconfined	451	PCV	Quat. alluvials	Non-Bedrock	451	0	0	0
Moorabbin	GMA	SRW	Unconfined and Confined	2,700	PCV	Brighton Group	Non-Bedrock	2,612	57	1,171	1,171
Nepean	GMA	SRW	Unconfined	6,110	PCV	Bridgewater Formation	Non-Bedrock	6,012	77	3,908	2,404
Wandin Yallock	WSPA	SRW	Unconfined	3,008	PCV	Older Volcanics	Non-Bedrock	3007.9	193	565	506
Upper Goulburn	GMA	GMW	Unconfined	8,568	PCV	Various	Alluvials and bedrock	6,115	140	N/A	2,222

^{*1} note – Alexandra, Kinglake and Spring Hill GMAs were subsumed into the larger Upper Goulburn GMA. They have been included separately here because they define concentrated areas of irrigation usage that do fall within the study area.

Additional groundwater resources also occur in the study area, outside of the listed GMAs, in what is known as 'unincorporated area'. Within the study area, the western Port Phillip, eastern Port Phillip and Westernport groundwater catchments (Victorian Water Accounts, 2015-16) have an entitlement of 27,680 ML and recorded usage of 5,043 ML. In respect to the mapped Land Capability Class 1,2 and 3

agricultural land, this highlights that there are additional areas of land with potential access to irrigation water supply.

Groundwater Flow Systems (GFS) mapping (Figure 13) is another data source used to provide an indication of potential groundwater resource or impact condition on high value agricultural land. GFS were originally developed in the former National Land and Water Resources Audit (NLWRA) as a framework for dryland salinity management in Australia. They "characterise similar landscapes in which similar groundwater processes contribute to similar salinity issues, and where similar salinity management options apply" (Coram et al., 2001). Although GFS provide an indication of the nature of the surficial aquifers only, in some landscapes, such as river valley alluvials, this may also be a good indicator of well drained soils overlying potential irrigation suitable aquifers. Where there is coincidence of Land Capability Class 1 or 2 agricultural land and favorable GFS, some additional analysis is recommended to refine our understanding of resource potential in specific locations. Figure 14 provides an enlarged view of GFS in the Dandenong Ranges region.

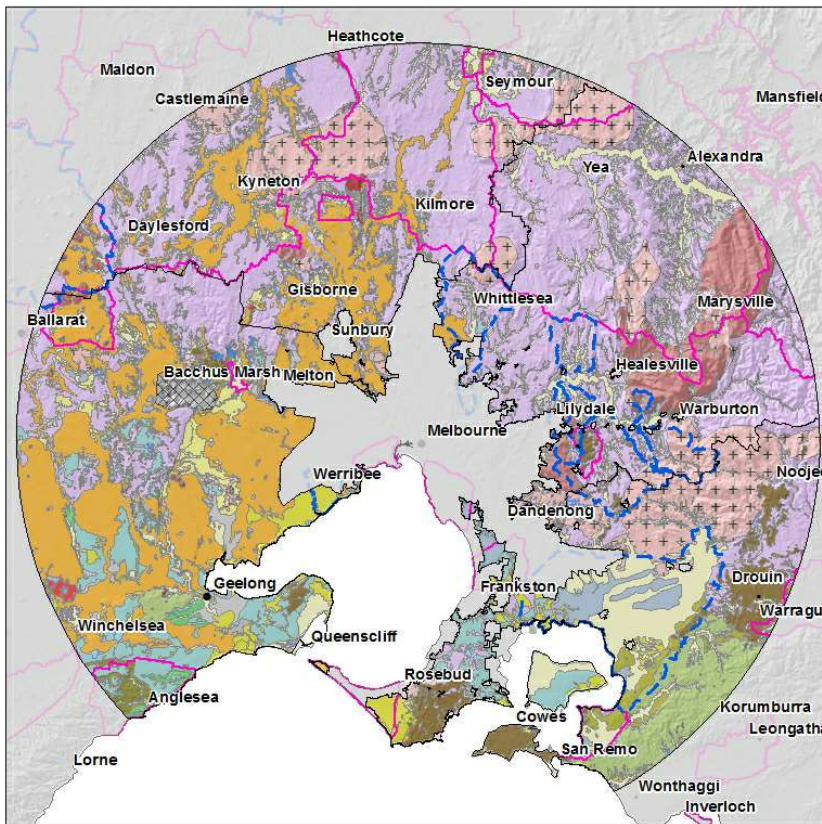
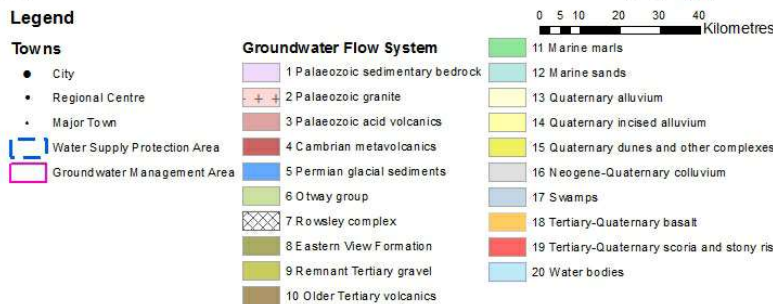
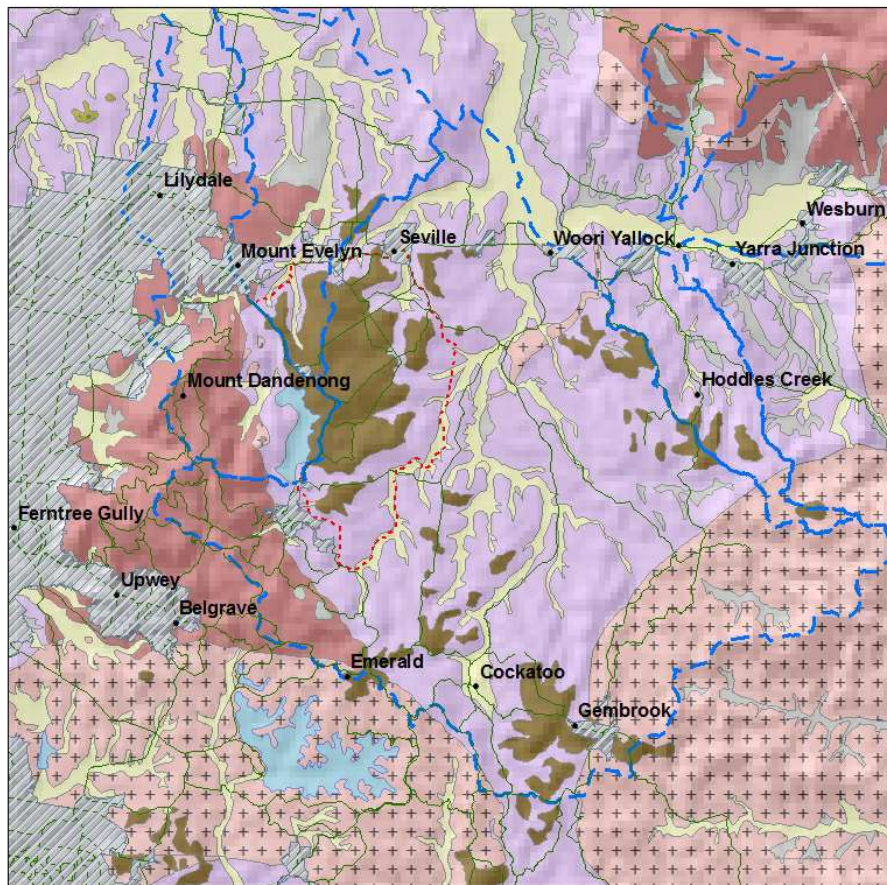


Figure 13. Groundwater Flow Systems (GFS) defined on basis of surficial geology.





Legend

Towns

- Large Town
- Town
- ▨ Urban Growth Boundary
- Main Road (Sealed)
- ▭ Water Supply Protection Area
- ▭ Groundwater Management Area

Groundwater Flow System

- | | |
|----------------------------------|---|
| 1 Palaeozoic sedimentary bedrock | 11 Marine marls |
| 2 Palaeozoic granite | 12 Marine sands |
| 3 Palaeozoic acid volcanics | 13 Quaternary alluvium |
| 4 Cambrian metavolcanics | 14 Quaternary incised alluvium |
| 5 Permian glacial sediments | 15 Quaternary dunes and other complexes |
| 6 Otway group | 16 Neogene-Quaternary colluvium |
| 7 Rowsley complex | 17 Swamps |
| 8 Eastern View Formation | 18 Tertiary-Quaternary basalt |
| 9 Remnant Tertiary gravel | 19 Tertiary-Quaternary scoria and stony rises |
| 10 Older Tertiary volcanics | 20 Water bodies |

Figure 14. Enlargement of an area in the Dandenong ranges region showing Groundwater Flow Systems (GFS). Note the Older Tertiary Volcanics GFS (olive-brown colour on map) east of Mt Dandenong that contains a highly developed groundwater resource (Wandin WSPA) and has highly capable soil (Ferralsols). The light green Quaternary alluvium GFS along the Yarra Valley and tributaries has good groundwater potential that could be valuable as part of an integrated urban-rural development water management plan.

3.6.2. Land subject to high watertable or subject to soil salinity threat

Watertable depth is a dynamic and location specific groundwater condition that has implications for land use and land value. Where the watertable is always deeper than about 3 metres below surface, agriculture can mostly be conducted without any consequence, whereas a shallow watertable can impede farming through reduced trafficability, cause soil degradation due to waterlogging, or increase soil salinity to levels that impact plant productivity and degrade soil structure. Mapping data is available for the study area in the form of a generated depth to water table surface that is a product of a highly developed methodology incorporating DTM base mapping, known point watertable depths and climatic data (Peterson, University of Melbourne). Two examples of this product are shown in Figures 15 and 16 below. In assessing agricultural land capability, land mapped as having a high watertable may or may not have an actual high watertable all the time, so other site and location data needs to be used to corroborate whether the threat of a high watertable or salinity should be taken into consideration. A corroborating piece of mapping is the State Salinity data, which captured all the mapping of saline land that occurred from the late 1970s to 2012, as also shown in Figure 12 (yellow shaded areas). The GFS mapping can help further refine HWT and Salinity threat and where certain GFS may be associated with a higher incidence of past land salinity occurrences.

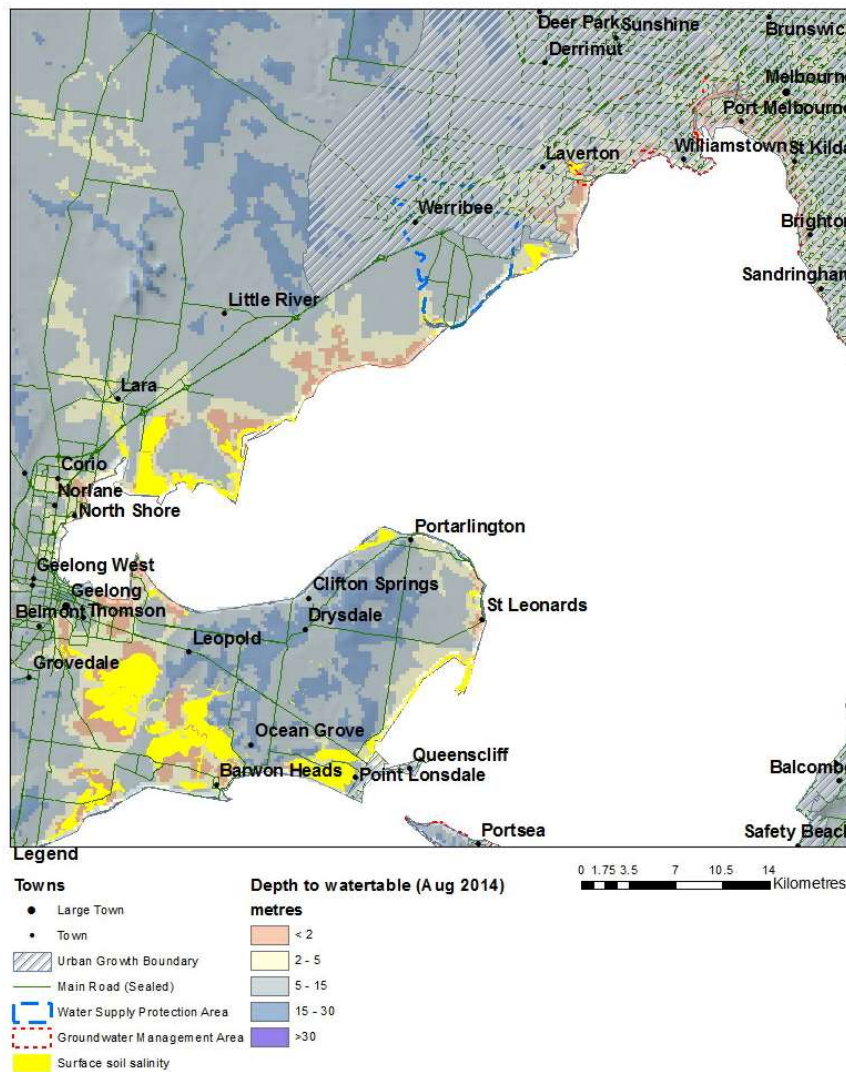


Figure 15. Enlargement of the study area north of Westernport Bay, showing modelled watertable depth below surface grid map from August 2014 (pink to blue shading) and cross hatching showing agricultural land capability classes

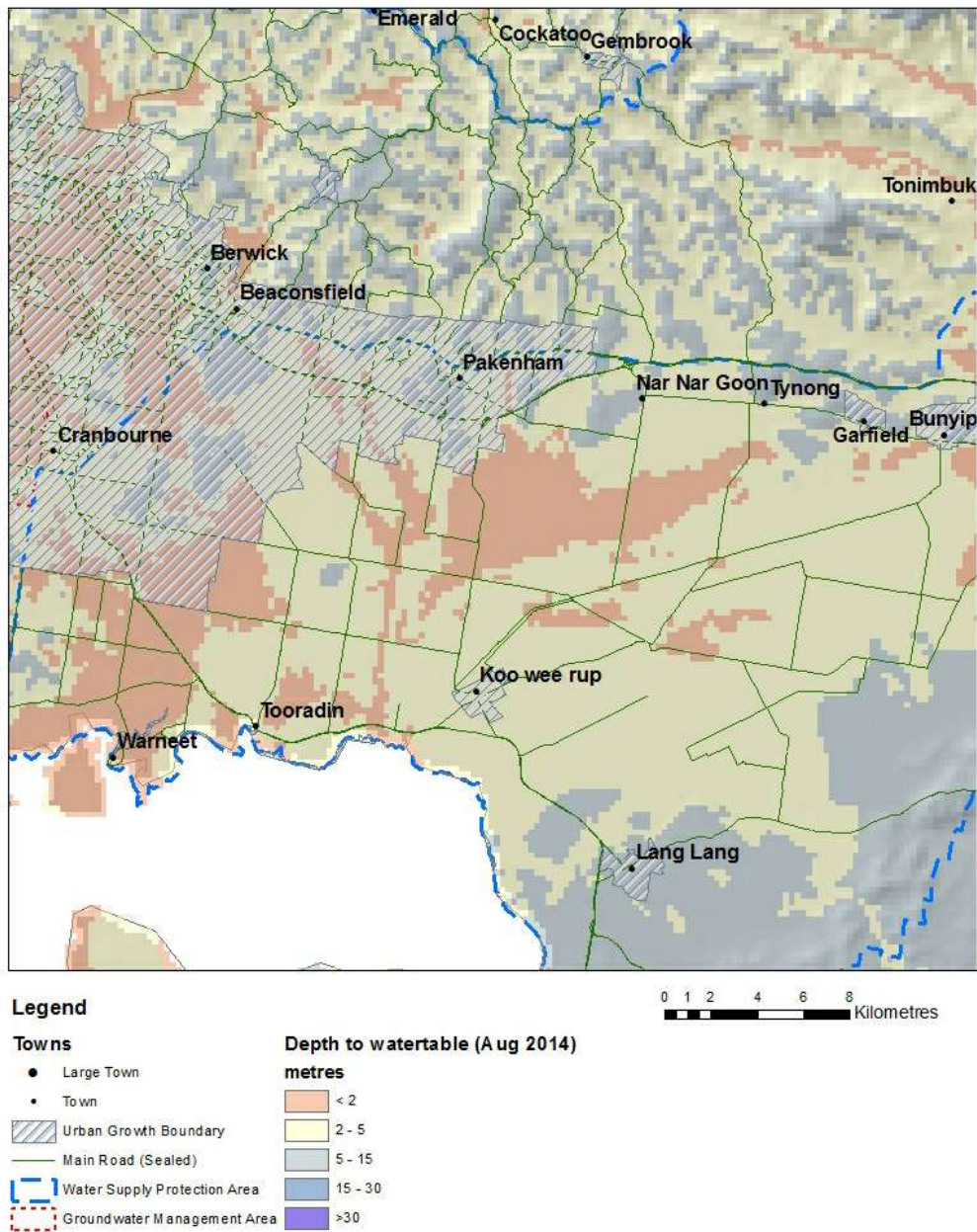


Figure 16. North-west side of Port Phillip Bay showing areas with high potential water table (pink and grey shading) and mapped salinity affected land (yellow shading). Note high density of irrigation bores to south-east of Werribee in the Deutgam WSPA. These bores provide irrigation water supply to market gardens as well as serving as watertable control. Note also much of the salinity mapped land may also coincide with Coastal Acid Sulfate Soils (CASS) in coastal areas.

3.6.3. Case studies of high value agricultural land and groundwater resources

Examples of high value agricultural land use and groundwater license holdings are at Clyde, Koo-Wee-Rup, Boneo, Wandin Yallock, Pearcedale Tyabb to Tooradin (unincorporated area), Werribee South (Deutgam GMA) and on, and north of, the Great Dividing Range; e.g. Kinglake area.

Figure 17 is an excerpt from Google Earth mapping of the Tooradin – Koo-Wee-Rup - Bunyip area showing Land Capability *Class 1, 2* and 3 land together with licensed bores. This shows a particularly high concentration of licensed bores that tap into the high quality and extensive middle depth Koo-Wee-Rup aquifer. To the north-east of Tooradin there is a strong co-incidence of a high concentration of licensed bores and higher capability agricultural land. Extensive areas of Class 3 land to the south and east of Lang Lang would become a more valuable resource where groundwater is available. This area provides a very clear example of where land should be afforded a high level of planning protection due to the combination of suitable (and proven) soils for intensive horticulture coinciding with a reasonably secure irrigation water supply.

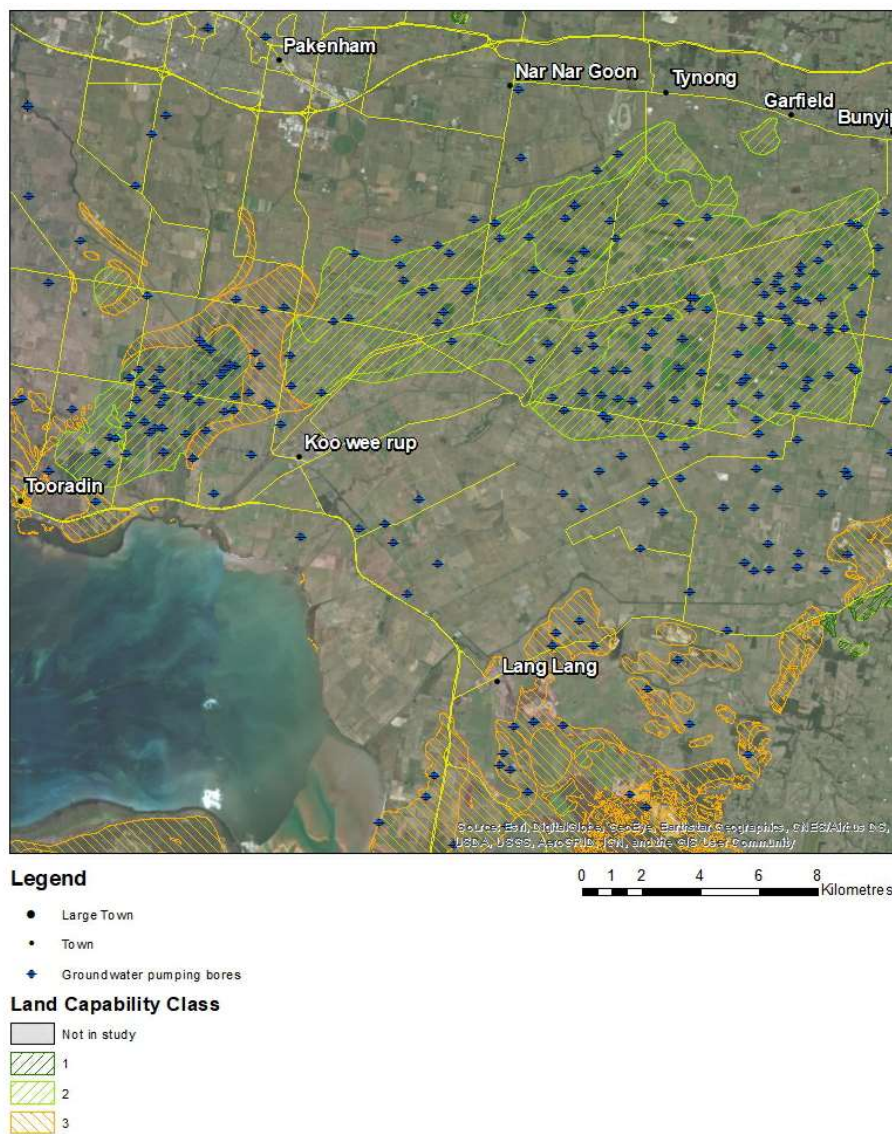


Figure 17. Koo-Wee-Rup area showing Land Capability *Class 1 and 2* land and licensed bores.

A second clear example of the coincidence of Land Capability Class 1 and 2 land and an important and a managed groundwater resource is the Wandin area SE of Lilydale (Figure 18). This already highly intensive horticultural area occurs over the Wandin Yallock groundwater management unit, which is an *Older Volcanics* aquifer that provides moderate yields of high quality (low salinity) water. The Port Phillip Groundwater Atlas provides more detailed descriptions of this GMU if required.

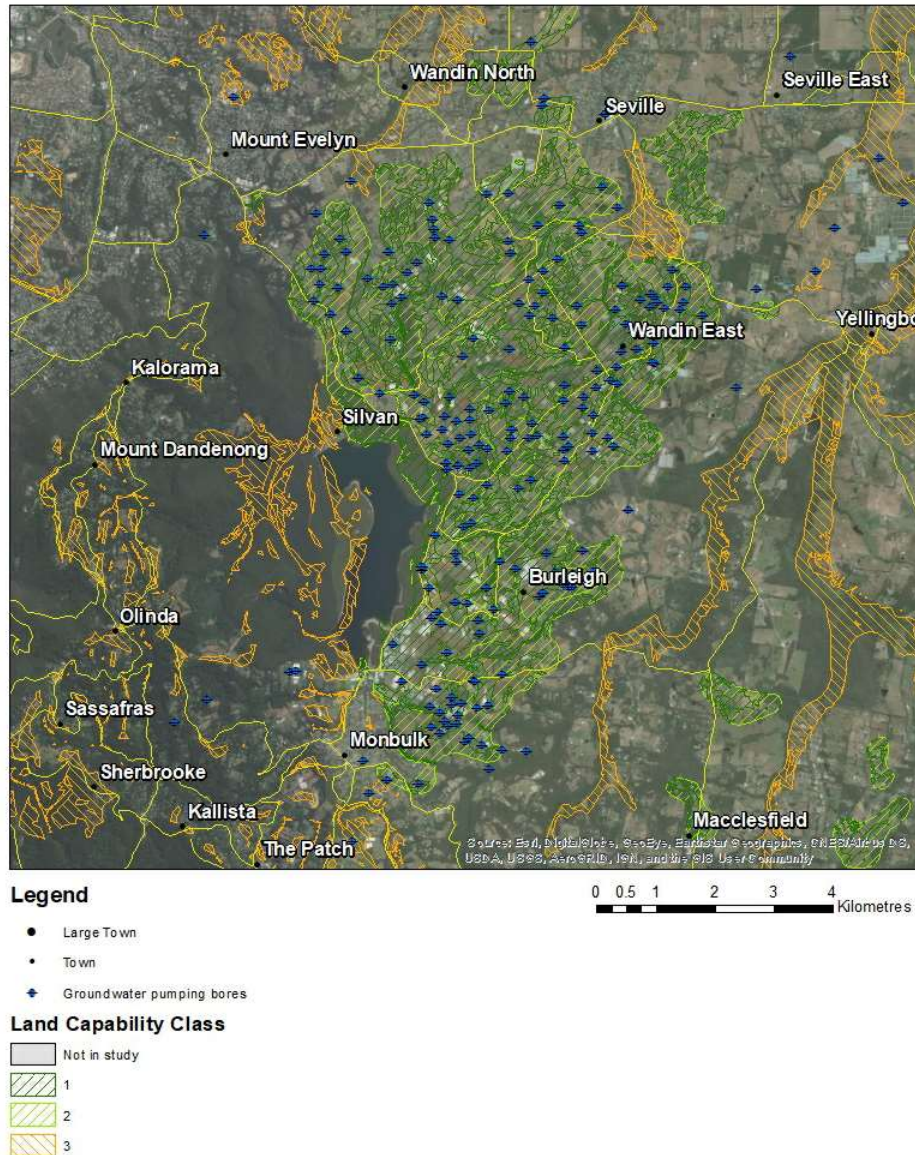


Figure 18. Wandin area, east of Silvan Reservoir, showing Land Capability Class 1 and 2 land and licensed bores.

The Kinglake region (see Figure 19) provides a case study of where the amount of Land Capability *Class 1* and *2* land is not large and/or contiguous, and where the density of licensed bores is not high, but the groundwater resource is well proven and historical agricultural production was high value. A few covered horticulture operations (e.g. #70485, Licensed for 66 ML) are still observed, but the intensity of development is nothing like the Wandin area. There may also be opportunities for areas of *Class 3* land capability to become a more valuable resource with available groundwater. Note that the northern side of the Divide is covered by the Goulburn Murray Water (GMW) managed Upper Goulburn GMU.

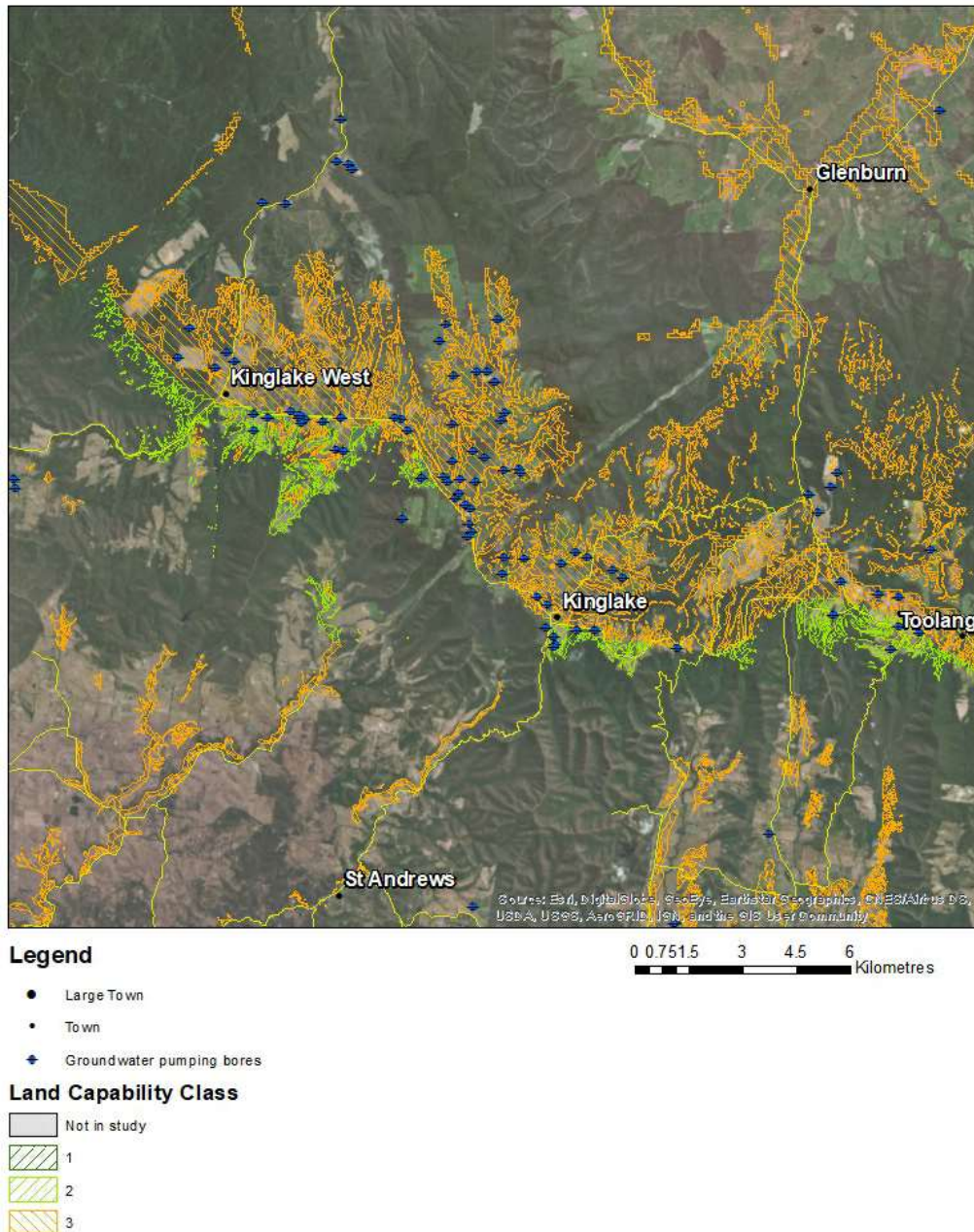


Figure 19. The Kinglake area has some *Class 1/2* land, but *Class 3* land that also has licensed bores may also be considered as potential for higher value due to the availability of reliable water.

3.6.4. Surface Water Supply Example Area.

The sizeable area of Land Capability *Class 1-3* land on the south-eastern Mornington Peninsula (Red Hill – Merricks – Flinders; see Figure 20) may present an opportunity to secure long-term irrigation supported agricultural production using *Class A* recycled water from the SE treatment plant. As the outfall is at Gunnamatta, and may pass close by, or through the area, this land could become more established and economically viable with connection to such a reliable water supply. A news article below (8 May, 2018) indicates there is local government support for such a development, and so protection of high value agricultural land would be an important factor in building a case for it.

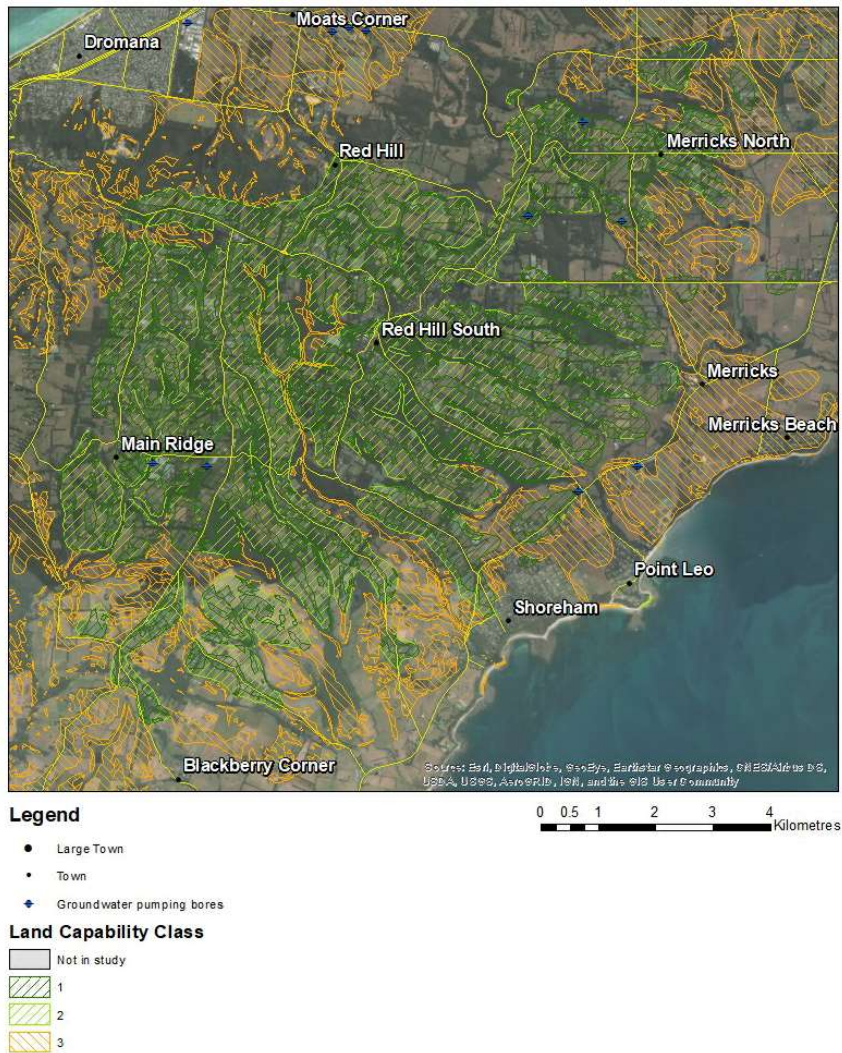


Figure 20. Land Capability *Class 1 and 2* in south-east Mornington Peninsula. Groundwater supply is limited, but recycled water could be supplied, securing production for the many vineyards in the area.

3.6.5. Managed Aquifer Recharge (MAR) or Aquifer Storage and Recovery (ASR)

A quote from SRW 2014 about Melbourne in 2050 provides some indication of the future potential role aquifers can play in an integrated water management cycle:

“By 2050 the population of Melbourne is projected to grow by over 3 million people to over 7 million. The current water supply will not meet the needs of this growth and, without alternative water supplies, the economy and environment will be impacted significantly. Groundwater is a potential supplementary water supply source and aquifers could be used for water storage”.

Presumably, the population in 2050 will require fresh, locally produced horticulture products produced by skilled horticulturalists through specialised and energy efficient supply chains. Ensuring a reliable, drought-proof water supply to underpin that production will need to make use of all available options, a key one of which is groundwater systems. Already, cities like Perth and Adelaide are implementing Aquifer Storage and Recovery (ASR) to improve drought resilience, and within the study area, nine ASR schemes were being trialed or in operation by 2014 (SRW, 2014). DEDJTR (2016) conducted a detailed review of MAR potential for the support of Victorian Agriculture. That study found that in the Melbourne area, both successful and unsuccessful ASR trials have been documented since the 1970s.

For identified high value agricultural land assets in the study area, ASR has the potential to enhance the irrigation water supply and help to secure Melbourne's important food production resource. Where existing groundwater use for irrigation is occurring, the possibility of enhancing supply security is unique to each system, from both the hydrogeology and the recharge supply side. For example, the large Koo-Wee-Rup system presents an opportunity to utilise increased volumes of urban stormwater from the Pakenham growth corridor via an integrated water management plan. Suitable Groundwater Flow Systems (GFS) occur where the Quaternary Alluvium overlaps the edges of the Palaeozoic Granite foothills and drainage lines enter former wetland 'Swamp' GFS areas. The need to manage flood flows that particularly impact the town of Koo-Wee-Rup, and disallow development on flood prone land, presents an opportunity to site artificial wetlands along existing drainage lines (especially the now channelised drains that run into Westernport Bay) and in flood prone areas, where retarding basins and wetlands can enhance recharge to the underlying water supply aquifers and improve water quality flowing into Westernport Bay.

A comprehensive analysis of MAR/ASR is beyond the scope of this study but, as a matter of policy, land-use planning that assess the future of high quality agricultural land should consider an evaluation of integrated water management opportunities as they pertain to enhancing the productivity of that land. There is also an opportunity to better manage the impact of urban development on catchment hydrology (including flooding) and the role of ASR in future water resource planning can provide alternative water supplies for urban amenity need as well.

3.6.6. Surface water supplied irrigation

Southern Rural Water (SRW) supplies several rural water use areas with both raw surface water and reclaimed water (treated wastewater). The surface water irrigation supply schemes they operate are the Werribee and Bacchus Marsh systems, both of which support a valuable market gardening area. During the 'Millennium Drought', water shortages encouraged innovation in conjunctive supply, irrigation efficiency, stormwater and wastewater re-use and ASR. Future predictions of rainfall uncertainty suggest such measures will become more necessary.

Two new sources of water that could be considered in relation to planning for Melbourne's growth are storm-water and reclaimed water. The preservation of agricultural land in strategic locations that can utilise these water sources has great value for serving Melbourne's future population with local fresh food production needs. It is therefore a logical contributing factor in the agricultural land value analysis, where a combination of suitable soils in locations down-gradient from urbanised areas (for storm-water capture), or in the vicinity of reclaimed water treatment plants, provides future food production opportunity. The presence of suitable aquifers also provides additional value if they occur under land needed for wastewater irrigation in the buffer zones around Waste Water Treatment Plants (WWTPs). They can provide both ASR opportunity and a mechanism to manage high watertables and salinity that can arise from wastewater irrigation activity.

The SE WWTP has an outfall pipeline to Gunnamatta that conveys 'class A' treated water to ocean outfall. As a press article indicates (Plate 20) there is already interest in such development, so identified capability *Class 1, 2, 3* agricultural land for both direct irrigation and, if there are suitable aquifers, could provide opportunity for ASR to further improve drought security.



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 Mornington Peninsula Leader, Melbourne
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 ASR: AUD 893 • words: 281 • Item ID: 950085188

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Page 1 of 1

PENINSULA

Plan in the pipeline

Council unveils proposal to “drought proof” Peninsula using treated sewage

Christian Tatman

A PROPOSAL to use treated sewage to “drought proof” the Mornington Peninsula has received strong backing from farmers.

Mornington Peninsula Council has called on the State and Federal Governments to fund a pipeline that would enable treated sewage from the Eastern Treatment Plant at Carrum to be directed to peninsula farmers.

Mayor Bryan Payne said the project had state significance.

“It requires a commitment

of funding as part of food security, employment, tourism, fire prevention and climate change policies,” he said.

“The importance of the development of recycled water infrastructure on the peninsula for food security and maintaining sporting and environmental assets has been clearly demonstrated by droughts, water restrictions of the past and even by the lack of rain over the last three months.”

Cr Payne said the development of a pipeline and system for the peninsula was vital to

provide water security to the wide variety of agricultural activities.

Council wants funding for a new pipeline — running off the existing pipe pumping out treated sewage at Boags Rock, Gunnamatta — so the Class A recycled water can be used by peninsula farmers.

Victorian Farmers Federation peninsula branch president Eddie Matt described the council’s proposal as bold.

“It’s been particularly dry

this year. If they were to create more water (availability) ... it would open more oppor-

tunities for small acreages to produce more crops,” he said.

Mr Matt said the Class A recycled water produced by the treatment plant was ideal for irrigation.

Nepean Liberal candidate Russell Joseph strongly backed the council’s proposal.

Mr Joseph said it was a “travesty” the water was being dumped via the Boags Rock outfall when it could be used by farmers.

Plate 20. Article from Mornington Peninsula Leader newspaper (8 May 2018) on potential use of treated wastewater to boost agriculture.

3.6.7. Groundwater Quality and Contamination

Salinity of groundwater is a major factor in the suitability of the supply for its intended use, particularly for horticulturally sensitive crops. Water salinity varies widely horizontally and vertically in groundwater systems, so fitness for purpose can only be known once drilled. Indications of water quality throughout the study area are mapped for different depth zones, with Figure 21 illustrating salinity variability in the shallow aquifers. Groundwater contamination from past industrial, or other human derived contamination sources, is unlikely to be a factor affecting much of the land area, but it could be an issue at some localities. EPA known locations (Groundwater Quality Restricted Use Zone – GQRUZ) data is shown in the groundwater atlas (SRW, 2014), a copy of which is presented in Figure 22. This highlights that most GQRUZ sites are located within the urban zone, but a few in agriculturally significant locations such as Bacchus Marsh and to the east of Frankston may have implications for the agricultural use of that groundwater.

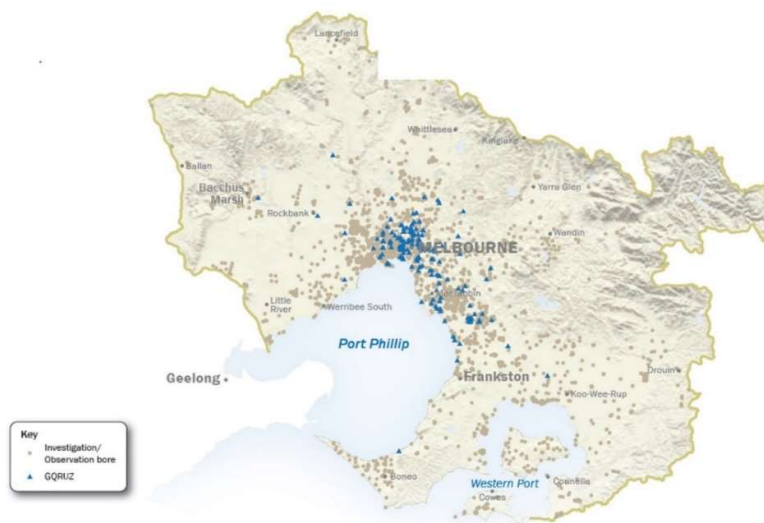


Figure 21. Groundwater salinity in shallow aquifers (based on Port Phillip Groundwater Atlas, SRW, 2014).

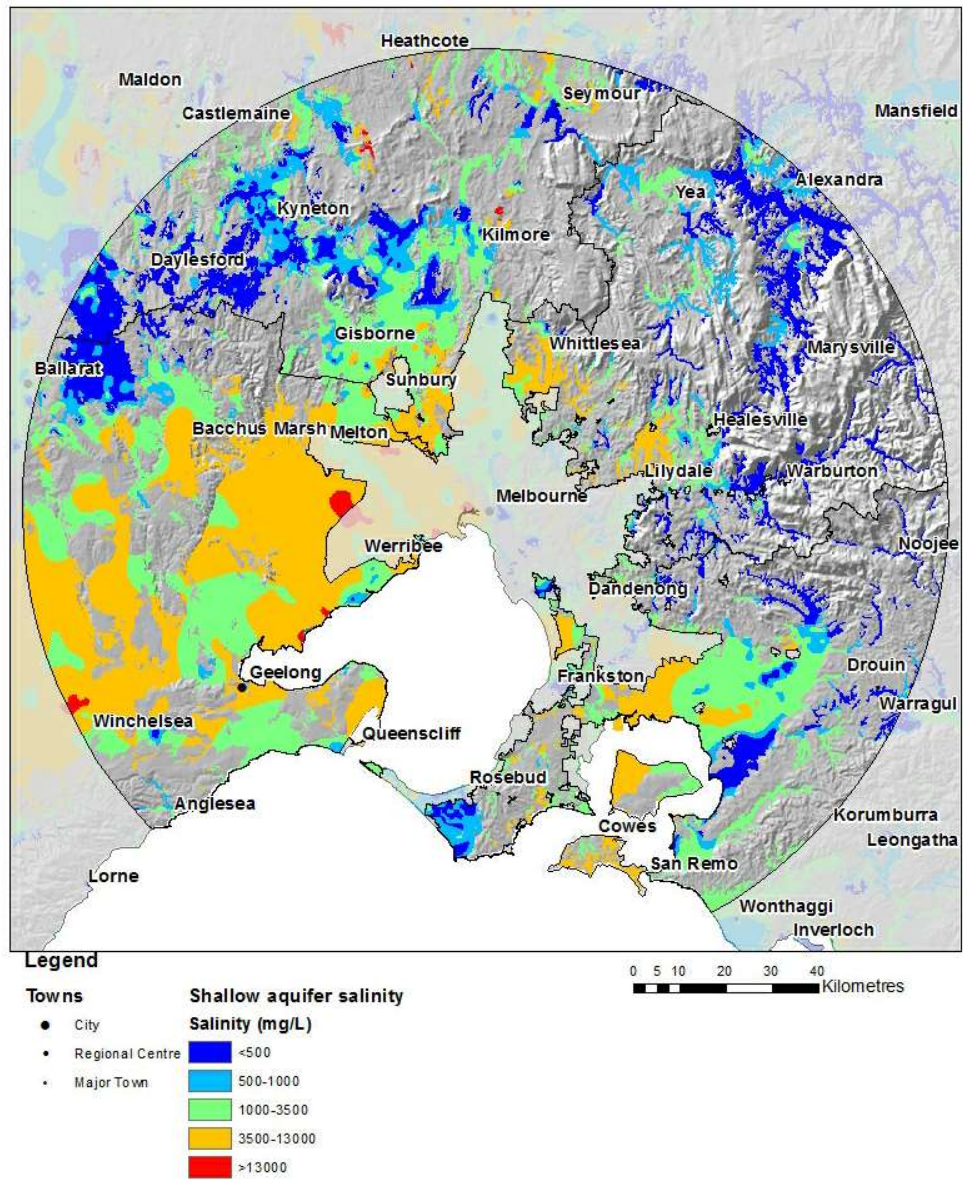


Figure 22. Groundwater Quality Restricted Use Zone (GQRUZ) sites within the Port Phillip and Westernport catchment – reproduced from p. 27, SRW 2014 (data sourced from EPA).

3.6.8. Summary of groundwater implications

A detailed description of groundwater aspects for each identified high value agricultural land area throughout the 100 km radius study area would be a substantial undertaking. What has been identified in this work is how groundwater can be an important additional aspect in determining the future value of agricultural land in the Melbourne growth zones.

The most significant areas are those where favourable soils coincide with known groundwater resources. Within the study area, about 40 GL of available groundwater supply is managed for sustainability objectives under formal plans. Any Land Capability *Class 1,2* and *3* lands found in these management areas, having proven bore yields and suitable water quality, can be readily identified, as shown in Figure 23. If development applications, or strategic planning analysis, has implications for identified high production soils, the water supply infrastructure (both surface and groundwater) and future managed aquifer recharge and recovery potential will need to be assessed in more location-specific detail.

Suitable aquifers and hydrogeological conditions that could be utilised for integrated water management opportunities are known to occur, but proving this potential requires further investigation. There are known locations where Aquifer Storage and Recovery (ASR) has or is being investigated, such as near Werribee. Land that has existing groundwater irrigation development and where there are nearby surface water supplies suitable for recharge need to be systematically identified for all areas under near-term development pressure.

Groundwater based threats to high value agricultural land can also be identified at the study area scale to a limited degree of certainty. Areas with high watertables and soil salinity can be mapped against near-term development proposals to identify these threatening processes. In other development circumstances (such as urbanisation on high watertable areas) the likelihood of favourable hydrogeological conditions, that can be utilised to mitigate or manage these threats, can also be evaluated. Groundwater Flow Systems (GFS) mapping can assist in such evaluation, but site-specific studies are necessary at an individual development scale.

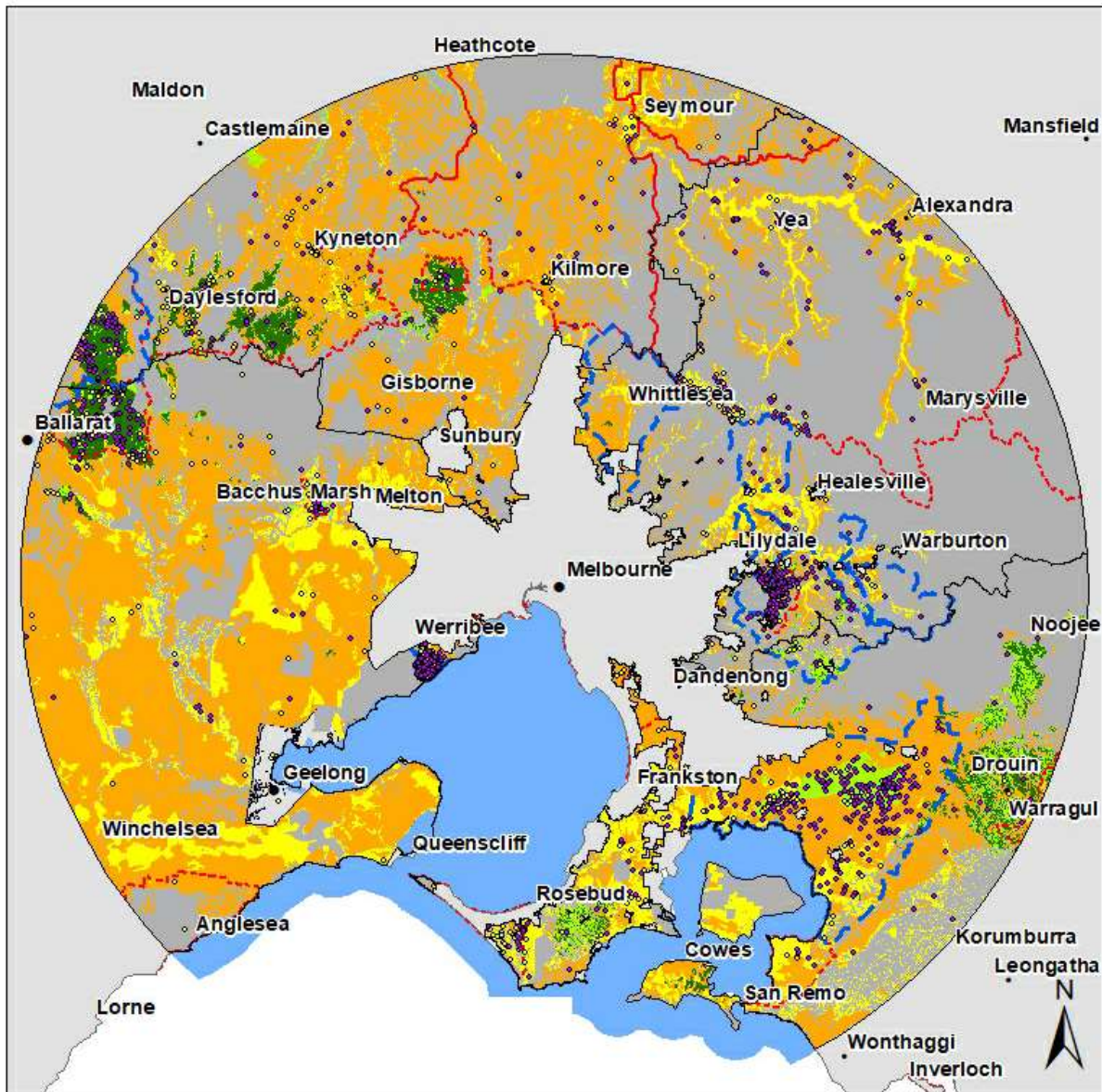


Figure 23. Overview map showing Land Capability Classes, Groundwater management Areas (GMAs) and locations of licensed groundwater bores. Where favorable soil, landscapes and water resources coincide in established areas, with appropriate infrastructure and specialised labour, this will help to better define higher value agricultural land.

4. CONCLUSION

This project has harmonised legacy mapping and collated all available soil and landscape data within Melbourne's peri-urban zone (100 km radius of CBD). A Land Capability approach has resulted in the classification of mapped land units into five classes of which *Classes 1, 2 and 3* can be considered potentially suitable for future identification as 'Strategic Agricultural Land' (SAL). An assessment of current intensive agricultural land use (including horticulture and dairying) and strategic soil types shows a strong association with many of the higher rated land capability areas. Land Capability provides the underlying foundation for any future assessment of soil and landscape-based SAL. Suitability assessments (usually for specific agricultural commodities) are useful to understand various potential land use options for this land, and factor in climate change projections. In addition, other non-biophysical criteria will also influence the designation of SAL, such as existing infrastructure, availability of good quality and reliable water supply and transport.

Known groundwater resources that have been identified can be readily assessed in relation to land capability from the mapping data gathered. At local strategic land planning and allotment scale (e.g. land just outside of the current growth boundary), Land Capability *Class 1, 2 and 3* land can be given groundwater resource condition status with high certainty where it falls within a Groundwater Management Area (GMA) and especially where there is currently licensed and utilised groundwater associated with allotments. Lower certainty applies where there are favorable Groundwater Flow Systems (GFS) mapped but an unproven resource, and a low likelihood of a viable groundwater resource applies to any identified Land Capability *Class 1,2 and 3* land that overlies bedrock geology.

5. RECOMMENDATIONS

- Further ground-based soil and landscape assessment and mapping is recommended for higher-capability areas. This will better define potential areas suited to agricultural production, particularly if additional water resources become available (e.g. via new pipelines). In these priority areas, additional disaggregation of soil/landscape mapping would be beneficial, together with additional on-ground soil site assessment. This would improve the confidence ratings associated with land capability assessments and the determination of Strategic Agricultural Land (SAL) and enable finer scale mapping to better meet planning requirements.
- Discussions with planners would be beneficial to assist them to better understand various land resource assessment products. Some field-based extension (e.g. soil pit field days) might also be a useful approach to assist planners better understand the soil and land resource that relates to planning decisions.
- A more detailed assessment and mapping of current land use is warranted to build on the work undertaken in this project. Improved mapping of dairy farms, horticulture and broadacre cropping is warranted, particularly in areas more capable for higher value agriculture.
- For known high value agricultural areas facing short term (<5 years) development pressure, outputs from this study could be used to undertake a more detailed analysis of the future agronomic value of key locations. This could focus on testing and development of land suitability assessment methods that are tailored to planning strategy needs and produce outputs that planners require.
- In known locations, identified above, groundwater resources and conjunctive water use opportunities could be further investigated to help define the highest capability agricultural areas. Further on-ground assessment and mapping of key soil/landscapes would be warranted in areas where new water opportunities become available.
- For known high value production, groundwater supported areas, such as Werribee South, Wandin area and Koo-Wee-Rup (and others), further delineation of their agronomic future within the context of Melbourne's growth strategy should be undertaken.

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7. REFERENCES

Brown, I., Towers, W., Rivington, M and Black, H.I.J. 2008. Influence of climate change on agricultural land-use potential: adapting and updating the land capability system for Scotland. *Climate Research* 37:43-57.

Coram, J.E., Dyson, P.R., and Evans, W.R. 2001. An Evaluation Framework for Dryland Salinity. National land and Water Resources Audit Dryland Salinity Project. Bureau of Rural Sciences, Canberra.

Cotching, B. (1995). Long term management of krasnozems in Australia. *Aust. J. Soil and Water Cons.* 8:1 (pp 18-27).

DEDJTR 2016. Managed Aquifer recharge potential for Victorian Agriculture. Agriculture Research Technical Report (CMI# 105796).

Department of Natural Resources and Environment. 2004. Identification and preliminary risk assessment of prime development zones in the greater Melbourne area for recycled water use. Centre for Land Protection Research, Bendigo.

FAO (1976). A framework for land evaluation. *Soils Bulletin* 32, Food and Agriculture Organization, Rome.

FAO (1983) Guidelines: land evaluation for rainfed agriculture. *Soils Bulletin* 52, Food and Agriculture Organization, Rome.

GMW 2012. Loddon Highlands water supply protection area groundwater management plan. Prepared under the supervision of the Loddon Highlands Water Supply Protection Area Consultative Committee, November 2012. Available as .pdf document from: www.gmw.com.au

GMW 2013. Upper Goulburn groundwater management area local management plan. July 2013. Available as .pdf document from: www.gmw.com.au

Government of Victoria. 1991. A Review of Rural Land Use in Victoria. Part 1: The Loss of High Quality Agricultural Land as a Planning issue and Part 2: Rural Land Use Policy and Planning Issues. Department of Agriculture and Office of the Environment, Department of Conservation and Environment.

Kininmonth, I. 2000. Identifying areas of agricultural significance, *Miscellaneous Publication* 15/2000. Agriculture Western Australia, Perth.

Klingbiel, A.A. & Montgomery P.H. 1961. Land capability classification. *Agriculture Handbook* 210, US Department of Agriculture, Washington, D.C.

NSW Government. 2013. Interim protocol for site verification and mapping of biophysical strategic agricultural land.

NSW Office of Environment and Heritage. 2012. The land and soil capability assessment scheme. Second approximation. A general rural land evaluation system for New South Wales. Office of Environment and Heritage, Department of Premier and Cabinet NSW.

Queensland Government. 2010. Strategic cropping land – Policy and planning framework Discussion Paper. Department of Infrastructure and Planning.

Queensland Government. 2011. Protecting Queensland's strategic cropping land – Guidelines for applying the proposed strategic cropping land criteria. Land Planning, Department of Environment and Resource Management.

Read, V.T. 1988. The concept of prime agricultural land: a Western Australian perspective, *Resource Management Technical Report* 72, Department of Agriculture, Perth, <https://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1064&context=rmtr>

RMCG, 2011. Value of (Groundwater) services to Southern Victoria. RM Consulting Group.

Rowe, R K R, Howe, D F & Alley, N F (1981) Guidelines for Land Capability Assessment in Victoria. Soil Conservation Authority, Victoria.

Sojka, R.E. & Upchurch, D.R. 1999. Reservations regarding the soil quality concept. Soil Science Society of America Journal 63 1039-1054.

Southern Rural Water, 2011. South West Victoria Groundwater Atlas. Available as .pdf document from: www.srw.com.au

Southern Rural Water, 2014. Port Phillip and Westernport Groundwater Atlas. Available as .pdf document from: www.srw.com.au

SRW, 2014. Westernport Groundwater Catchment Statement, January 2014. Available as .pdf document from: www.srw.com.au

SRW, 2016. West Port Phillip Bay Groundwater Catchment Statement, June 2016. Available as .pdf document from: www.srw.com.au

SRW, 2017. East Port Phillip Bay Groundwater Catchment Statement, January 2017. Available as .pdf document from: www.srw.com.au

Swan, I.R. & Volum. A.G. 1984. Assessment of agricultural quality of land in Gippsland. Research project series No.134. Department of Agriculture, Victoria.

Tille, P., Stuart-Street, A. & van Gool, D. 2013. Identification of high quality agricultural land in the Mid West region: stage 1 – Geraldton Planning Region. Second edition. Resource Management Technical Report 386. Western Australian Agriculture Authority.
<https://www.agric.wa.gov.au/sites/gateway/files/RMTR%20386%20HQAL%20Geraldton%202nd%20edition.pdf>

van Gool, D., Maschmedt, D.J. & McKenzie, N.J. 2008. Conventional land evaluation. In Guidelines for Surveying Soil and Land Resources. Eds. NJ McKenzie, MJ Grundy, R Webster and AJ Ringrose-Voase. CSIRO Publishing.

van Gool, D. 2005. Land evaluation standards for land resource mapping: guidelines for assessing land qualities and determining land capability in south-west Western Australia. Technical Report No. 181. Agriculture Western Australia Resource Management, Perth.

Victorian Eco-Innovation Lab, University of Melbourne (2013) Mapping Melbourne for land capability: assessing the agricultural capability of Melbourne's peri-urban area. VicHealth.

APPENDIX 1 – VARIOUS AUSTRALIAN APPROACHES FOR ASSESSMENT OF SIGNIFICANT AGRICULTURAL LAND

Western Australia

The former Department of Agriculture and Food (DAFWA) documented the requirement to define and identify prime agricultural land in the 1980s. Viv Read (1988) introduced the concept of 'prime agricultural land' in a discussion around the idea of protecting these areas in WA. Information from this report was included in the Western Australian Planning Commission's DC 3.4 Rural Land Use Policy (1992). The definition compiled by Read included agronomic and environmental factors, but also considered additional details such as infrastructure and the significance of relative location. By 2002 the concept of 'prime agricultural land' had evolved into the term 'priority agricultural land' (SPP 2.5) based on further input from DAFWA (Kinmonth 2000). Essentially, this term was derived from agricultural areas of state or regional significance and was recommended as a zone in town planning schemes to clearly identify and protect such areas.

Some local governments managed to zone 'priority agricultural land', but most found it challenging to interpret multiple land capability maps and combine this with water resource information. This led to a new approach, known as 'High Quality Agricultural Land' (HQAL) mapping, that combines soil, land capability, water resource and rainfall data in a way that highlights the most productive and versatile areas for either irrigated or broadscale agriculture. Land use planners can use this information, in consultation with local communities, to identify and protect priority ag land in their local planning schemes. This planning process does not, however, apply to mining developments in WA (Percy 2015).

Land capability assessments of the soil-landscape mapping units that formed an integral part of the process of identifying HQAL have been based on the methodology of van Gool (2005). Modifications have since been made to meet the specific requirements of the process and to include land uses not covered in that report. Capability classes are assigned to the unmapped Zone Land Units (ZLUs) for individual land uses, using a five-class rating system, from Class 1 land (very high capability) to Class 5 land (very low capability):

- 1 – Very high – with very few physical limitations present and easily overcome and negligible risk of land degradation.
- 2 – High - minor physical limitations affecting either productive land use and/or risk of degradation. Limitations can be overcome by careful planning.
- 3 – Fair - moderate physical limitations significantly affecting productive land use and/or risk of degradation. Careful planning and conservation measures required.
- 4 – Low - high degree of physical limitation not easily overcome by standard development techniques and/or resulting in high risk of degradation. Extensive conservation measures required.
- 5 – Very low - severe limitations. Use is usually prohibitive in terms of development costs or the associated risk of degradation.

DAFWA developed land capability maps, by applying the methodology described above to existing soil-landscape mapping, for a variety of land uses, each colour coded according to the proportion of Class 1, 2, 3, 4, and 5 land. Examples related to specific types of land use are shown in Figure 1 below.

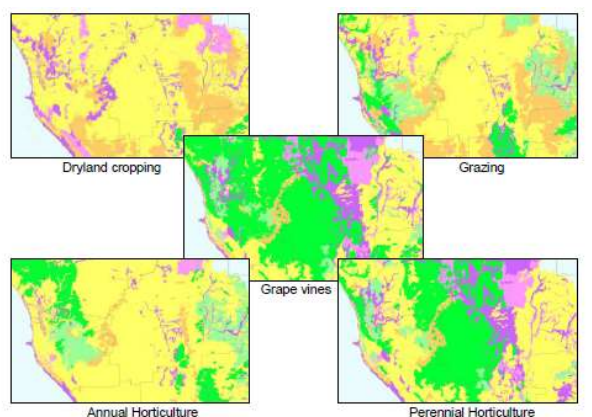


Figure 1. Land capability maps for specific land uses.

While the more complex style of mapping, as shown in Figure 1, can be quite useful for examining potential of individual parcels of land, it was viewed that there are problems in its application for broader scale planning (state, regional or local level). Some of these problems included that:

- Mapping can appear very intricate when viewed at a broad scale, resulting in the 'big picture getting lost in the detail'.
- The legend is complex and can be difficult to interpret.
- Assimilating information provided by numerous different industry or commodity-specific capability/suitability maps into a coherent overview of the 'best land' is conceptually difficult.

DAFWA undertook a more recent assessment of High Quality Agricultural Land (HQAL) in the Geraldton Planning Region (Tille et al., 2013). The aim of this study was to identify high quality agricultural land (HQAL) that exhibits a combination of qualities that are valuable to the agricultural industry and worthy of protection for future production potential. This pilot project developed and tested a methodology for identifying areas of HQAL at a regional and local planning scale. It aimed to synthesise a range of land capability, water resource and other data related to land use into a more easily understood format and able to be readily incorporated into the planning process. The link to the underlying information should also remain accessible and transparent.

From the WA perspective, HQAL identifies the best available land with access to water for agriculture in a specific area. Priority agricultural land gathers information about land and water, identified in the HQAL process, and combines it with social and economic requirements for the agricultural industry such as distance to market, labour availability and infrastructure. The combination of information can be used by planners and help determine the relative importance of different areas on a broader state and regional scale. Many components need to be considered for HQAL to be clearly identified, including soils and landforms; land capability; rainfall for broadacre agriculture; groundwater and surface water supplies for irrigated agriculture.

The Geraldton project also analysed current crop performance across the region and attempted to predict potential trends in the agricultural industry. In areas with few groundwater resources, the emphasis was on broadacre cropping - where relative wheat yields are related to growing season rainfall - along with land resources. In areas of moderate to good groundwater allocations, horticultural production was more of a focus. When rainfall and groundwater information was combined with land capability, areas of higher production potential became more obvious. Consequently, the project had two themes of land use that focus on agricultural potential and require access to good quality land and water, i.e. irrigated agriculture and broadacre cropping. Land 'flexibility' was an important consideration in this approach. Some land may have a high capability for one specific crop, or land use, but poorer capability for other crops or uses. At times, when a certain crop is popular, the land most suitable for it may be the most valuable in a region. However, once that crop ceases to perform as well in the marketplace that land may be considered a less valuable resource in comparison to land more suited to a range of well performing crops.

This project aimed to reduce the number of complex-style maps, while making the simplified style of mapping more definitive. A direct link between the two styles was created with the simplified style mapping being derived from the more complex. In the complex style, the multiple maps showing capability for a variety of specific land uses were combined to produce two maps of agricultural potential—one for broadacre agriculture and one for irrigated agriculture. Broadacre agriculture encompassed the production of rain-fed field crops (using wheat as the benchmark) as well as raising livestock on rain-fed pastures. Irrigated agriculture tends to be a much more intensive form of production in which horticultural and other crops (such as fruit, vegetables and flowers) are grown with water delivered through irrigation systems (usually sprinklers and drippers).

Figure 25 shows the final map of Agricultural Land Area (ALA) groupings for the Geraldton planning region.

Figure 24. Final map of Agricultural Land Areas in the Geraldton Planning Region of WA.

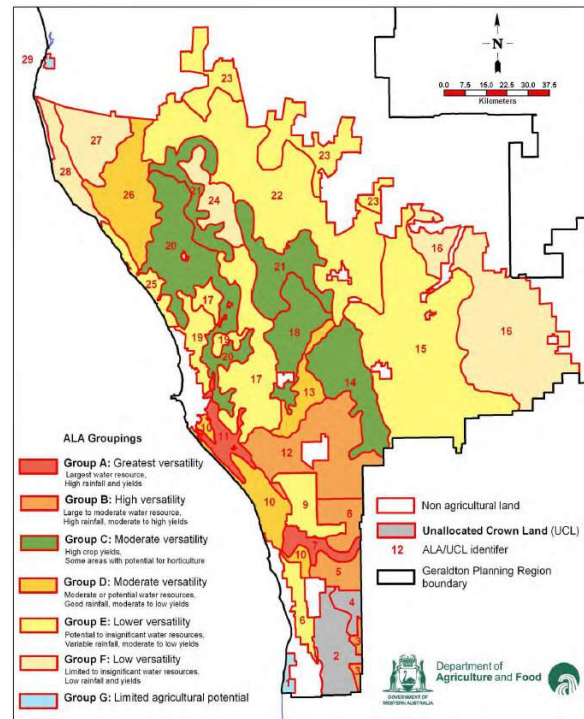


Figure A Grouping of Agricultural land areas in the Geraldton planning region

New South Wales

A number of land mapping projects and associated rule sets have been developed around the protection of valuable agricultural land in NSW, including

1. Farmland Protection Mapping
2. Biophysical Strategic Agricultural Land (BSAL)
3. Important Agricultural Land (IAL) Mapping

The Northern Rivers Farmland Protection Mapping Project, covering the Richmond, Tweed and Brunswick catchments, commenced in 2003/2004 and was completed in 2005. The similar Mid North Coast Farmland Mapping Project commenced shortly after completion of the Northern Rivers and was completed in 2006. This project was based on Local Government Areas (LGAs) rather than catchments. Both projects were initiated by the NSW Department of Planning and involved a collaborative effort from the predecessors of the NSW Office of Environment and Heritage and the NSW Department of Primary Industries. Local government representatives also provided input. The protection of farmland was an important aspect of the Catchment Management Plans that provided the impetus for the projects. Both projects relied on soil landscape mapping (existing, draft and some new) to derive classes of agricultural land based on: slope, soil depth, soil type (fertility), drainage, rock outcrop, stoniness, waterholding capacity, specific landscape aspects (e.g. flooding). The Northern Rivers project identified (i) state significant land; (ii) regionally significant land and (iii) other farmland. Due to differences in landscape properties, the Mid North Coast project only identified (i) regionally significant farmland and (ii) other farmland. To be mapped as farmland, land satisfying the criteria also had to have a minimum area of contiguous occurrence (500 – 1000 ha, depending on the category). The “other farmland” category also included those lands that satisfied all criteria other than the minimum area. The farmland mapping projects have provided important baseline data for local government planning and the North Coast State Regional Plan (Department of Planning).

The NSW Department of Planning and Environment undertook a more recent assessment of Biophysical Strategic Agricultural Land (BSAL) in 2012 (NSW Government, 2013), driven by the need to manage growth in the mining and coal seam gas industries. It identified land with the highest quality soil and water resources critical to agriculture. These lands intrinsically have the best quality landforms, soil and water resources that are inherently capable of sustaining high levels of productivity and that require minimal management practices to maintain this quality. BSAL is capable of being used sustainably for intensive uses such as cultivation. Such land is inherently fertile and generally lacks significant biophysical constraints. Regional maps of BSAL met the following criteria:

- Properties with access to a reliable water supply, defined by:
 - rainfall of 350 mm or more per annum (9 out of 10 years), or
 - a regulated river (maps show those within 150 m), or
 - a 5th order or higher unregulated river (maps show those within 150 m), or
 - an unregulated river which flows at least 95 per cent of the time (maps show those within 150 m), or
 - highly productive groundwater sources, as declared by NSW Office of Water. These are characterised by bores having yield rates greater than 5L/s and total dissolved solids of less than 1,500 mg/L and exclude miscellaneous alluvial aquifers, also known as small storage aquifers.

and

- land that falls under soil fertility classes ‘high’ or ‘moderately high’ under the Draft Inherent General Fertility of NSW (OEH), where it is also present with land capability classes I, II or III under the Land and Soil Capability Mapping of NSW (OEH).

or

- land that falls under soil fertility classes ‘moderate’ under the Draft Inherent General Fertility of NSW (OEH), where it is also present with land capability classes I or II under the Land and Soil Capability Mapping of NSW (OEH).

Figure 26 provides a diagrammatic version of the interim protocol for site verification and mapping of Biophysical Strategic Agricultural Land (BSAL).

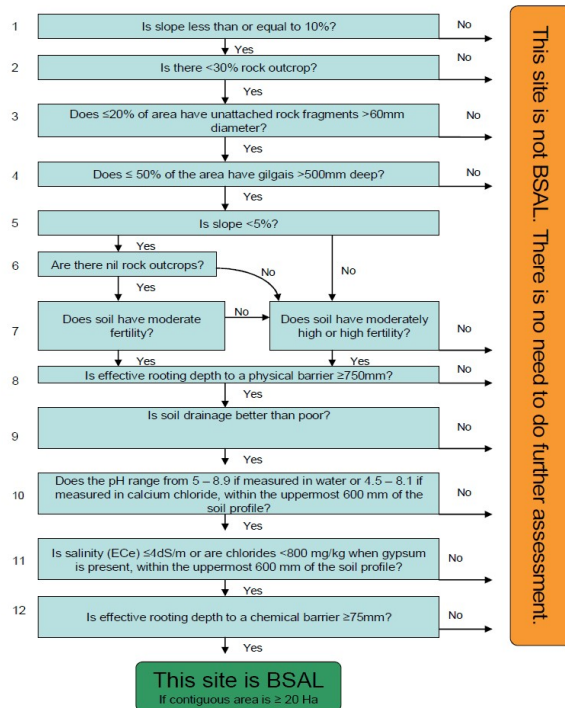


Figure 25. Diagrammatic version of interim protocol for site verification and mapping of Biophysical Strategic Agricultural Land (BSAL), NSW Government (2013)

Important Agricultural Land (IAL) mapping is currently being undertaken by NSW Department of Primary Industries (DPI) with a nested 'Hotspot' project carried out by NSW Office of Environment and Heritage (OEH). Both Projects are in partnership with the NSW Department of Planning and Environment (DP&E). NSW DPI has produced 'A guideline to identifying important agricultural lands in NSW' <https://www.dpi.nsw.gov.au/agriculture/lup/agriculture-industry-mapping/pub16-323-a-guideline-to-identifying-important-agricultural-lands-in-nsw>

IAL is considered 'highly suitable' for agricultural industries and it is envisaged that the mapping it will enable improved decision making about current and future agricultural land uses. IAL mapping includes four products: current agricultural land use maps, biophysical maps, socio-economic maps and agricultural industry maps. These can be used solely or in combination to support improved planning to:

- reduce land use conflict.
- provide certainty for agribusiness.
- choose appropriate zones for non-agricultural development.
- enable compatible development in zones that permit agriculture.
- support essential agricultural assets.
- support the agricultural supply chain.
- identify future opportunities for agricultural industries.

Nested within the IAL Project is the 'IAL Hotspot' Project in which 40 priority regional centres in NSW are being targeted. Datasets will be produced to provide accurate information on soil type, soil fertility and soil and land capability data at a local scale for a 20 km radius area around each of these centres. The Hotspot project will provide an order of magnitude greater resolution to IAL mapping in areas around regional centres which are often the areas with greatest development pressure and threat to agricultural lands from urban and peri-urban developments.

Queensland

The Queensland government introduced the Strategic Cropping Land Act 2011 (Qld) to address the competing interests of unconventional gas extraction and agricultural activities. The identification of Strategic Cropping Land (SCL) has been driven by public concern over land-use conflict that has increased markedly in recent years, following the rapid expansion of exploration for resources, such as coal, coal seam gas and liquefied natural gas. In 2014, the Queensland government passed the Regional Planning Interests Act 2014 (Qld) ('RPI Act') to repeal the 'SCL Act' and put in place a more stringent agricultural protection regime. The purpose of the RPI Act is described as: to protect strategic areas of the most regionally significant agricultural production and provide certainty for the future of towns while also establishing a framework for successful co-existence between the different sectors.

Strategic Cropping Land (SCL) is land that is, or likely to be, highly suitable for cropping due to a combination of favourable soil, climate and landscape features. The Queensland Government considers that the best cropping land, defined as SCL, is a finite resource that must be conserved and managed for the longer term. As a general aim, planning and approval powers should be used to protect such land from developments that lead to permanent alienation or diminished productivity. A preliminary map of candidate areas for strategic cropping land was developed using the best available agricultural soil and land use data. The map shows land with the following attributes:

- soil properties that support sustainable crop production, including soil depth and drainage that does not limit production and/or machinery operation.
- landscape properties including slopes not exceeding certain parameters and limited erosion potential.
- land use has previously included cropping or the current use does not preclude the land being used for cropping.

Other criteria that have been used to define strategic cropping land include:

- water availability from rainfall or irrigation that is sufficient to match crop requirements
- infrastructure necessary for transport or processing of primary produce is in place or can be provided.
- legal constraints, including conservation and vegetation clearing controls and land tenure, do not preclude the land from being used for cropping.

For Queensland, the identification of SCL needs to be accurate, supported by measurable data and able to be applied consistently to cropping areas across the state. Mapping of SCL indicates the location and extent of relevant land resources across the state and is based on the criteria listed below. Specific criteria to differentiate between classes of SCL were developed for consideration to ensure that standards of development assessment can be matched to the significance of the resource:

- SCL Class 1 – suitable for cropping with negligible limitations.
- SCL Class 2 – suitable for cropping with minor limitations that either reduce production or require more than the simple management practices of Class 1 land to maintain economic production
- SCL Class 3 – suitable for cropping with moderate limitations that either reduce production or require more than the simple management practices of Class 2 land to maintain economic production.

The on-ground assessment of whether land is SCL is based on eight criteria, as shown in Table 1 below sourced from 'Protecting Queensland's strategic cropping land – guidelines for applying the proposed strategic cropping land criteria (Queensland Government, 2011). These criteria are inclusionary and have clear threshold levels (i.e. when one criterion is not met, then the site area is not SCL and further assessment at that site ceases). Criteria are ordered from the more easily determined 'above-ground' measures, like slope and rockiness, to more complex measures, such as salinity and soil water storage capacity, that may require laboratory analysis. Only when all criteria are met is the site deemed SCL. This structure minimises assessment requirements for landholders and development proponents and maintains the technical integrity of the system, whilst ensuring it can be applied as easily and efficiently as possible. While the criteria are consistent across the cropping areas, there are different threshold values that define specific soil and landscape features within each zone. The five regional zones (e.g. Eastern Darling Downs) accommodate regional differences in climate, landforms and cropping systems (as shown in Table 1).

Table 2. Summary of criteria for identifying Strategic Cropping Land (SCL) sourced from the 'Strategic Cropping Land policy and planning framework Discussion Paper (Queensland Government 2010).

Table 1: Summary of criteria for identifying SCL

Criteria	Criteria thresholds for each SCL zone				
	Western Cropping	Eastern Darling Downs	Coastal Queensland	Wet Tropics	Granite Belt
1. Slope	≤ 3%	≤ 5%			
2. Rockiness	≤ 20% for rocks > 60 mm diameter				
3. Gilgai microrelief	< 50% of land surface being gilgai microrelief of > 500 mm in depth				
4. Soil depth	≥ 600 mm				
5. Soil wetness	Has favourable drainage				Has satisfactory drainage
6. Soil pH	For non-rigid soils, the soil at 300 mm and 600 mm soil depth must be greater than pH 5.0. For rigid soils, the soil at 300 mm and 600 mm soil depth must be within the range of pH 5.1 to pH 8.9 inclusive.				
7. Salinity	Chloride content < 800 mg/kg within 600 mm of the soil surface	EC _{1:5} < 0.56 dS/m within 600 mm of the soil surface			
8. Soil water storage	≥ 100 mm to a soil depth or soil physico-chemical limitation of ≤ 1000 mm	≥ 75 mm to a soil depth or soil physico-chemical limitation of ≤ 1000 mm	≥ 50 mm to a soil depth or soil physico-chemical limitation of ≤ 1000 mm	≥ 25 mm to a soil depth or soil physico-chemical limitation of ≤ 1000 mm	

APPENDIX 2 – LEGACY LAND RESOURCE STUDIES COVERING THE GREEN WEDGE AND PERI-URBAN AREA

Study	Date	Scale
Bannockburn_land_system http://vro.agriculture.vic.gov.au/dpi/vro/coranreg.nsf/pages/corangamite_land_systems_bannockburn	1981	1:25 000
Mitchell_Shire_land_units_100k http://vro.agriculture.vic.gov.au/dpi/vro/gbbreg.nsf/pages/gb_lcs_mitchell	1996	1:100 000
Gippsland_Lakes_Catchments_land_systems http://vro.agriculture.vic.gov.au/dpi/vro/egreg.nsf/pages/eg_landform_Land_systems_gipps_lakes	1984	1:250 000
Upper_Yarra_Valley_Dandenong_Ranges_land_systems http://vro.agriculture.vic.gov.au/dpi/vro/portreg.nsf/pages/port_land_systems_upper_yarra	1976	1:60 000
Cathedral_Ranges_Acheron_Valley_land_units http://vro.agriculture.vic.gov.au/dpi/vro/gbbreg.nsf/pages/gb_lcs_cathedral_acheron	1996	1:25 000
Cranbourne_KooWeeRup_land_units http://vro.agriculture.vic.gov.au/dpi/vro/portreg.nsf/pages/port_soil_survey_cranbourne	1996	1:50 000
Corangamite_land_units http://vro.agriculture.vic.gov.au/dpi/vro/coranreg.nsf/pages/soil_landform_lra_pdf/\$FILE/clra_final.pdf	2003	1:100 000
Otway_Ranges_land_systems http://vro.agriculture.vic.gov.au/dpi/vro/coranreg.nsf/pages/corangamite_land_systems_otway	1981	1:250 000
Melbourne_northern_hinterlands_land_systems http://vro.agriculture.vic.gov.au/dpi/vro/portreg.nsf/pages/port_land_systems_nth_melb	1981	1:250 000
Romsey_land_units http://vro.agriculture.vic.gov.au/dpi/vro/nthcenreg.nsf/pages/nthcen_landform_romsey	1994	1:25 000
Newham_Woodend_land_units http://vro.agriculture.vic.gov.au/dpi/vro/nthcenreg.nsf/pages/landuse_lcs_newham_woodend	1992	1:25 000
Loddon_River_map_units http://vro.agriculture.vic.gov.au/dpi/vro/nthcenreg.nsf/pages/nthcen_landform_geo_loddon_land	1988	1:100 000
Bungaree_land_systems http://vro.agriculture.vic.gov.au/dpi/vro/coranreg.nsf/pages/corangamite_land_systems_bungaree	1979	1:100 000
Greater_Melbourne_land_units	n/a	1:250 000
Melbourne_Land Resource Data Atlas	1985	1:25 000
Goulburn_Broken_land_units	2003	1:100 000
Mid_Goulburn_land_units	1990	1:250 000

Murrindindi_Shire_land_units	2001	1:100 000
Mitchell_Shire_land_units_25k http://vro.agriculture.vic.gov.au/dpi/vro/gbbreg.nsf/pages/gb_lcs_mitchell_map	1996	1:25 000
Euroa_South_land_units	1984	1:2 000 000
Cardinia_Land_Units10k http://vro.agriculture.vic.gov.au/dpi/vro/portreg.nsf/pages/pp_lca_cardinia	1997	1:10 000
Cardinia_Land_Units25k http://vro.agriculture.vic.gov.au/dpi/vro/portreg.nsf/pages/pp_lca_cardinia	1997	1:25 000
Campaspe_River_catchment_land_systems http://vro.agriculture.vic.gov.au/dpi/vro/nthcenreg.nsf/pages/nthcen_landform_campaspe_river	1987	1:250 000
Eildon_land_systems http://vro.agriculture.vic.gov.au/dpi/vro/gbbreg.nsf/pages/gbb_landform_landsys_lake_eildon	1977	1:250 000
Whittlesea_land_unit_capability	1949	1:12 000
Westernport_Catchment_land_units http://vro.agriculture.vic.gov.au/dpi/vro/portreg.nsf/pages/port_soil_survey_westernport	1975	1:123 000
South_West_Gippsland_Land_Units http://vro.agriculture.vic.gov.au/dpi/vro/wgreg.nsf/pages/wg_soil_detailed	1997	1:100 000
Gippsland100_Land_Units http://vro.agriculture.vic.gov.au/dpi/vro/wgreg.nsf/pages/wg_soil_detailed	2000	1:100 000
South_West_Victoria_land_units http://vro.agriculture.vic.gov.au/dpi/vro/coranreg.nsf/pages/soil_landform_mm_soils	1987	1:250 000