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MARGARET RIVER

REGIONAL PROFILE



AHA Viticulture

On behalf of the Grape and Wine Research and Development Corporation (GWRDC)

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MARGARET RIVER REGIONAL PROFILE

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INTRODUCTION

The aim of this profile is to describe the major soil types of the Margaret River region and their implications for vineyard management. In this context, the focus of vineyard soil management will be on those decisions made to improve the health, growing habits, and general balance of the grapevine. How these factors in turn affect wine quality has been a subject of debate for many years. The extent to which the managed state of a soil type impacts on wine quality is a complex matter that is both difficult to quantify and qualify. The French have historically described this relationship via the concept of "terroir", a term used under numerous definitions. Van Leeuwen (1996, after White, 2003) describes terroir as a "complex notion which integrates several factors…" - the natural environment (soil, climate, topography), biology (variety, rootstock), and human (of wine, wine-making, history). Another definition is that terroir is a dynamic concept characterising both permanent (eg, soil, environment) and temporary factors (variety, cultural management, winemaking). The intricacies of the relationship between the soil and 'vine quality', and the subsequent relationship between 'vine quality' and 'wine quality' are outside the scope of this document. Rather, emphasis will be placed on managing the soil for optimal grapevine growing conditions, so that the potential is there for quality winegrape production.

The management of a vineyard involves a number of interfaces that exist mutually and therefore influence one another. Vineyard soils are the interface between the *atmosphere* and the *lithosphere* (the earth's mantle). The *hydrosphere* is the interface between the soil and bodies of water, and the *biosphere* comprises the biological life of the soil (plants, animals, insects, and microorganisms).
All of these interfaces are influenced to some degree by our choice of vineyard management techniques.

The most suitable soils for vineyards can be loosely categorised as those which:

- Have a pH between 5.0-8.5 in the rootzone, and less than 7.5 in the topsoil.
- Resist water and wind erosion.
- Are not readily waterlogged, especially during the growing season.
- Have at least 15% aeration of total soil volume at field capacity.
- Consistently hold at least 50mm of readily available water in the rootzone, at -60kPa soil moisture tension.
- Are deep enough to allow active root growth; 60cm in irrigated vineyards, 100cm in dryland situations.
- Have an adequate water infiltration rate to avoid pooling of surface water.
- Do not contain toxic concentrations of salts, chloride, metals, or trace elements.

(Nicholas,2004).

Area: Geology/Geomorphology/Soils

By Peter Tille[1]

The Margaret River Region covers three major soil-landscape zones; the Leeuwin Zone encompasses the older vineyards in the west, the Donnybrook Sunklands in the east; and the Swan Coastal Plain in the north-east. A small area of the Scott River Plain is also present in the south-east. The Dunsborough Fault (which runs from Dunsborough down to

[1] This text is taken from a Department of Agriculture and Food Publication currently in preparation titled "The Soils and environment of Western Australia's viticultural regions draft publication on the soils of Western Australia's viticultural regions"

Augusta, passing inland of Margaret River) separates the Leeuwin Zone from the Donnybrook Sunklands.

The Leeuwin Zone is underlain by the intensely deformed metamorphic rocks (including granite gneiss, porphyritic granite and anorthosite) of the Leeuwin Complex. Over this has formed the lateritic plateau of the Cowaramup Uplands (Tille and Lantzke, 1990) which has been dissected by a number of relatively shallow, undulating valleys (collectively known as the Wilyabrup Valleys).

The earliest sites to be selected for grape growing in the region were in the valley formed by the Wilyabrup Brook. The Forest Grove soils (*Loamy gravels* and *Duplex sandy gravels*) are the most common profiles in these valleys and they consist of lateritic colluvium lying over clay derived from the deeply weathered mantle. The topsoil is typically yellowish-brown loamy sand to sandy loam with up to 60% rounded ironstone gravels. This overlies mottled yellow clay at about 50 cm. Less common are the Keenan soils (*Friable red/brown loamy earths* and *Brown deep loamy duplexes*) derived from freshly weathered basement rock. Small pockets of *Pale deep sands* are also encountered in some plantings.

Many plantings are now found on the surrounding plateau surface where there is a mixture of the gravelly Forest Grove soils and the poorly drained Mungite soils (*Pale sandy earths*, *Grey deep sandy duplexes* and *Semi-wet soils*) along with pockets of *Shallow gravels* lying above ironstone within 80 cm depth.

On the western edge of the Leeuwin Zone a discontinuous ridge of sand dunes underlain by Tamala limestone runs along the coast between Cape Naturaliste and Cape Leeuwin. The soils are predominantly *Calcareous deep sands*, *Yellow deep sands* and *Red deep sands*. Although most of this area is National Park and unavailable for viticulture, some vines have been planted at the leeward foot of the dunes.

The Donnybrook Sunklands are inland of the Leeuwin Zone and overlie the sedimentary rocks of the Perth Basin. Here vines have been established on the undulating terrain of the Treeton Hills where a mixture of Forest Grove and Mungite soils has formed on deeply weathered mantle. There are also plantings on the flatter Yelverton Shelf in the north which contains a similar mix of soils with some *Yellow deep sands.*

In the north-east of the region the Perth Basin is overlain by Tertiary and Quaternary sediments of the Swan Coastal Plain. Here plantings are centred around Jindong on the Marybrook soils (*Red deep sands*, *Red sandy earths* and *Friable red/brown loamy earths*) formed on recent alluvium. Some areas of the less well drained Busselton soils (*Pale sandy earths*, *Pale deep sands* and *grey-brown sandy loams*) have also been planted.

Waterlogging is a problem on the Mungite and Busselton soils, and also on lower slopes where some vineyards have been established. Without the installation of subsoil drainage, part of the root zone is still saturated when vines start growing in spring. Excess vigour can be a problem on the fertile Marybrook and Keenan soils and special attention to trellising may be necessary (Gladstones, 1992). Similar problems occur on Mungite soils where the subsoil remains moist throughout the growing season, especially in the higher rainfall districts to the south of Margaret River.

Most soils are neutral to acid, with soil acidity generally being considered a minor problem since it can be overcome with liming. Many soils are deficient in phosphorus, potassium and calcium. Despite the high rainfall, nitrogen is the only nutrient where there are significant losses due to leaching in most soil types. With careful vineyard design and the use of cover crops and sod culture, water erosion does not seem to be the problem it was in the early years. However, erosion has been noted on some of the Mungite soils and shallow gravels, particularly during the establishment phase.

Soil-landscape mapping covering this entire region has published in the Busselton-Margaret River-Augusta Survey (Tille and Lantzke 1990a).

Figure 1. Geology of the South West Region

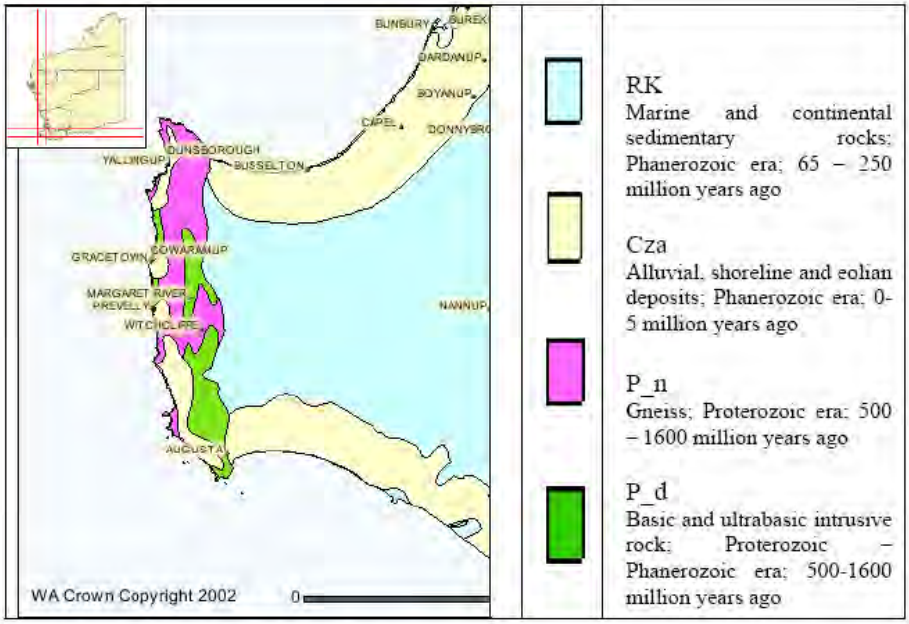


Figure 6.1.1 Geology of the South West Region.

Source: *Map produced using the Western Australian Atlas brought to you by the Western Australian Land Information System in partnership with the National Land and Water Resources Audit, a Program of the Natural Heritage Trust*

Citations: *AUSLIG (2000) GEODATA TOPO-250K (Series 1) – Localities*
Geological Survey of WA (1999) Western Australian Geological Polygons
Geoscience Australia (2001) Coast - 100k

Water Supply

By Peter Tille[2]

There are very limited groundwater supplies over the granitic rocks of the Leeuwin Block, and vineyards are largely reliant on gully wall dams and small soaks for water supplies. Not all properties have suitable sites for the construction of large dams.

On the Donnybrook Sunklands good dam sites are more common and many of the dams receive considerable recharge from seepage. In this area east of the Dunsborough Fault groundwater is available from superficial sediments on the coastal plains and aquifers in the Perth Basin. South of Margaret River in the Augusta Groundwater Management Sub-Area there are supplies in the superficial, Leederville, Lesueur Sandstone and Sues Coal Measure Aquifers. North of Margaret River in the Cowaramup Groundwater Management Sub-Area there are supplies in the superficial, upper Leederville, and Sues Coal Measure Aquifers. On the Swan Coastal Plain the Busselton-Capel Groundwater Management Area contains supplies in the superficial, Leederville and Sues Coal Measure Aquifers. Here many vineyards are irrigated with groundwater. Iron problems are often encountered in this water which needs to be treated by aeration and chemical control before it can be used for drip irrigation.

[2] This text is taken from a Department of Agriculture and Food Publication currently in preparation titled "The Soils and environment of Western Australia's viticultural regions draft publication on the soils of Western Australia's viticultural regions"

SOIL PARAMETERS

SOIL PHYSICAL PROPERTIES

Soil formation

Soil-forming factors include parent material (static and transported), climate, organisms, and the combined interaction of these factors over time. Parent material is the sub-stratum of the soil profile from which it developed. In some cases it is obvious that the overlying layers of the soil profile developed directly from weathering processes of the parent material beneath (mineral rock material such as granite, basalt, limestone, and shist). In others, the soil profile is made up of both the parent material *in situ*, and material transported via wind, water, ice, and gravity. Wind transported deposits are called *loess* (silt-sized particles), or *dunes* (sand-sized particles). *Alluvium* refers to deposits transported by streams, rivers, and flooding events, and *colluvium* refers to deposits displaced via gravity. Ice transported deposits are called *till*.

The Margaret River Region has abundant examples of soils which have been formed by transported parent material over long periods of time. These will be identified in the 'Soil Types' section of this report.

The soil profile

Vineyard soil types are commonly investigated via excavation (eg, soil pits and cores) to a depth of 2-3m. This allows for the visual assessment of the underlying vertical development of the 'soil profile'. A soil profile is characterised by distinct layers which are called *horizons*. These are classified according to a number of criteria; colour, texture, gravel/rock content, porosity, drainage potential, compaction, etc. Although there are various nomenclature systems for horizon types in Australia, for the purpose of this report a very simple system will be used, as outlined below:

Surface (top) soil – A1 horizon
Characterised by accumulated organic matter and maximum concentration of nutrients. Usually darker in colour than underlying horizons.

Subsurface soil – A2 horizon
Sometimes referred to as the E (eluvial) layer. This horizon is typified as a more leached zone of paler colour.

Subsurface soil – A3 horizon
A transitional layer between the A and B horizons.

Subsoil – B horizon (can be differentiated into B1, B2, B3)
The layer below the A horizon/s. Characterised by different colour, structure and consistence.

Subsolum – C horizon
The layer considered to be 'under the soil'. Comprised of *in situ* and transported parent material from which the layers above are formed. Common materials are deeply weathered rock, alluvial and windblown deposits, carbonates, buried soils and bedrock.

Boundaries between horizons may range from sharply defined (<5mm gradation) to diffuse

(>100mm gradation). The layers may be parallel to the soil surface (regular), or termed *waxy* (irregular).

Soil colour

Soil colour is often used as an indicator of soil condition. Dark surface colours indicate high organic matter levels and an increased ability to absorb and radiate heat. Light coloured subsurface soils are indicative of a highly leached environment with low organic matter and fertility. Exceptions to this are pale calcareous soil types. Red and orange soils indicate the presence of iron oxides under aerated conditions, implying good drainage. Pale grey-green and bluish grey colours indicate anaerobic conditions caused by waterlogging. Blotches or streaks of colour that are markedly different to the background colour are called 'mottles'. Where mottles are present, it can be assumed that waterlogging events are seasonal, as periodic oxidation has occurred.
Soil colours are recorded via a standard Munsell Colour Chart. Colours are arranged on the chart according to hue, value, and chroma. Hue relates to the dominant spectral colour of the soil, ranging from red (10R) through red-brown (5YR), yellow-brown (10YR), and yellow (2.5Y) to olive (5Y). Value refers to the lightness of the soil colour compared to white, with values ranging from white (8) to black (2). Chroma is the relative purity of the hue, as shown by the departure from neutral colours (termed "greyness"). Chroma ranges from no colour (0) to pure colour (8). These components of colour are recorded as *Hue value/chroma.* For example, a reddish brown soil would be recorded 5YR 5/4.

Soil texture

Soil texture is probably the most important of soil properties as it affects the available water capacity, nutrient availability, drainage and erosion potential. Texture is a measure of the relative proportions of sand, silt, and clay which are determined by their particle sizes.

Table 1. Soil particle size classes – fine earth (McLaren and Cameron, 1996).

Classes for fine earth fraction (mm)	
course sand	2.0-0.2
fine sand	0.2-0.02
silt	0.02-0.002
clay	<0.002

Table 2. Soil particle size classes – large particles (McLaren and Cameron, 1996).

Classes for large particles (mm)	
boulders	>200
very course gravel	60-200
course gravel	20-60

medium gravel	6-20
fine gravel	2-6

Soil texture is commonly assessed in the field via the use of a guideline table, similar to the one below:

Table 3. Field texture assessment (Nicholas, 2004).

Soil ball characteristics	Ribbon (mm)	Approx. clay content %	Texture grade	Broad grouping
Ball wont form	0	0-5	sand	sand
Ball only just holds together	5	5	loamy sand	sand
Sticky - balls just holds together, leaves clay on fingers	5-15	5-10	clayey sand	sand
Ball holds together - feels very sandy but spongy	15-25	10-20	sandy loam	sandy loam
Ball holds together - feels smooth & silky	25	25	silty loam	sandy loam
Ball holds together - feels smooth & spongy	25	25	loamy sand	loam
Ball holds firmly - feels sandy & plastic	25-40	20-30	sandy clay loam	loam
Ball holds firmly - feels smooth, silky & plastic	40-50	30-35	silty clay loam	clay loam
Ball holds firmly - feels smooth & plastic	40-50	30-35	clay loam	clay loam
Ball holds strongly - feels plastic	50-75	35-40	light clay	clay
Ball holds very strongly - feels like plasticine	>75	40-50	medium clay	clay
Ball hard to manipulate - stiff plasticine	>75	>50	heavy clay	clay

Soil structure

The term soil structure relates to the size, shape and development stage of soil particles held together as aggregates. Many soil types form well-defined aggregates called “peds”. Soils that are lacking peds, such as sands and massive soils, are classed as “apedal”. Aggregates formed at the soil surface or by cultivation are not true peds and are termed ‘fragments’ or ‘clods’. The consistence and friability of a soil is tested by aggregate strength in moist soils. The rate of water and air movement through a soil is directly proportional to its friability. Friability is improved with organic matter and reduced with sodicity.

Table 4. A scheme for determining the consistence of moist soil samples (McLaren and Cameron, 1996).

Consistence category	Behaviour of soil material in response to pressure between fingers
loose	non-coherent
very friable	crushes easily under gentle to moderate pressure and coheres when pressed together
friable	crushes easily under very gentle pressure but coheres when pressed together
firm	crushes under moderate pressure but is distinctly resistant
very firm	crushes under strong pressure, barely crushable
extremely firm	crushes only under very strong pressure, cannot be crushed between thumb and forefinger

Peds are generally grouped according to their shape and form; plate-like, prism-like, block-like and spheroidal.

Soil porosity

The way in which soil particles and aggregates are arranged within the soil profile determines the porosity of the soil. Porosity is essential in enabling the soil to store water and oxygen, allowing adequate drainage, root penetration and nutrient uptake. More important than total porosity is the distribution of pore spaces within the soil. A sandy soil, for example, having consistent size and distribution of pores drains faster than a clay soil with a majority of small pores. Along with other factors, soil porosity relates directly the relative permeability of a soil.

Soil permeability

The ability of a soil profile to transmit water vertically (i.e. internal drainage) is called 'permeability'. Permeability at the soil surface is referred to as the *infiltration rate*. A high infiltration rate is desirable in vineyard soils as it allows rapid recharge with water and avoids the likelihood of surface run-off and erosion. Soil permeability is influenced by soil porosity, impeding layers, texture, organic matter, root distribution, and clay content. Soils are classed as *slowly, moderately*, or *highly permeable*.

Soil depth

In vineyards, soil depth is generally considered in relation to the depth of the surface soil where the surface feeding roots reside. A depth of at least 15-30cm of friable soil is recommended for optimal grapevine growth (Coombe and Dry, 1988). Nicholas (2004)

classes optimal soil depths for root penetration at 60cm for irrigated vineyards, and 100cm in dryland situations.

Physical limitations in soil

Physical limitations in soils may cause barriers to root growth and obstruct water movement. Most limitations are observed in the subsoil. However, the deterioration of surface soil via excessive cultivation and wheel compaction can also create barriers. The following is a brief description of the common types of impeding layers in vineyard soils:

Hard rock
Continuous sheets of rock or stone that provides a permanent barrier to root growth. In situations where rock is a shallow, reasonably thin layer overlying softer material, deep ripping may be possible.

Partially weathered rock
Less of a concern that hard rock, partially weathered rock often contains cracks that allow some degree of root and water penetration.

Compact Sands
Very fine sands can become compacted naturally or mechanically. Although compacted soils can be broken up with a winged tine plough, re-settlement usually occurs unless irrigation is carefully scheduled.

Cemented pans
These are formed by the cementation of horizontally concentrated clays, carbonates or minerals. Pans vary in thickness but may block root growth and cause topsoil waterlogging even when very thin.

Subsoil clays
Poorly structured clays prevent root development by restricting growth to the surface of aggregates. When found at a depth of 20-40cm the use of gypsum, mounding, and deep ripping may be beneficial.

Water repellence and waterlogging

The negative effects of water repellence are demonstrated through in poor soil moisture storage, susceptibility to erosion, and reduced growth of cover crops (Nicholas, 2004). Water repellence is caused by the breakdown of plant debris which deposits waxy substances onto the soil surface. It is common in acidic and sandy soils. Cultivation to bring clay to the topsoil is one method used to overcome excessive repellence.

Waterlogged conditions can result in poor vine growth and should be avoided. There are a number of causal factors:

- Soils that lack adequate surface drainage.
- Perched water tables due to compacted layers in the subsoil.
- Poorly structured, low permeability clay subsoils.
- Rising water tables.
- Compaction caused by machinery.
- Plough shearing of clay soils which acts as a barrier to water percolation.

Remedial techniques to improve drainage in waterlogged soils range from relatively simple to extensive and costly. Minor surface waterlogging can be corrected with applications

of organic matter and gypsum. Moderate waterlogging may require deep ripping and deep placement of gypsum. Further benefits may be observed with planting of deep-rooted cover crop species. For severe and prolonged waterlogging, subsurface drainage may need to be installed.

Soil erosion

The most significant effect of erosion in vineyards is the removal of the nutrient rich topsoil, leaving behind more inert soil forms.
Three broad factors determine the potential water erodibility of the soil.

1. *Soil properties that affect aggregate formation and stability* – particle size distribution, clay content, organic matter, exchangeable cations, root volume, degree of slaking and dispersion.
2. *Topography* – erosive forces are greater on sloping and highly exposed land.
3. *Land Management* – bare cultivated soils are more susceptible to erosion than those under vegetation. Other issues include row orientation (especially on sloping land), use of windbreaks, and management of surface water.

Wind erosion is not common in vineyards, except during the establishment phase when vine canopies are not large enough to act as continual windbreaks. Even under these circumstances, it is only very dry or sandy soils that are particularly susceptible. Where wind erosion is a concern, the use of midrow vegetation (as opposed to bare soil) and windbreaks are advantageous.

Soil-water relations

Soil-water relations have been documented extensively and are very complex. The topic involves the interrelationships between the soil, plant and atmosphere. For the purposes of this profile, a summary of those factors that directly involve soil moisture content and irrigation will be provided.
Soil moisture can be measured by either *volumetric water content* or *soil water tension*. Volumetric water content is defined as the volume of water per unit volume of soil and is usually expressed as a percentage or in mm depth of water. Soil water tension provides information about how easily water can be taken up by the vine roots. It is a measure of how tightly water is held in the soil profile, and the suction required by the plant to extract water (expressed as kilopascals (-kPa) or centibars (cB)). As the soil dries out it requires more suction to obtain soil water and therefore the greater the –kPa reading. Gypsum blocks and tensiometers are examples of sensors which read soil moisture tension.

The following terms are commonly used in evaluating plant-available water:

Saturation Point (SP) – when all available pores of the soil are filled with water and the soil profile is saturated. In this situation, drainage is quite rapid.

Field Capacity (FC) - usually occurs 1-2 days after the soil has been saturated and the macropores in the soil profile have drained out to the point that water is readily available to the plant. FC is reached when soil moisture tension is measured between -2 and -8kpa.

Permanent Wilting Point (PWP) - when water is held so tightly by the soil that plant roots cannot extract it. Under these conditions the grapevine will typically collapse due to water stress and not recover. PWP is reached when soil moisture tension readings exceed -1500kPa.

Available Water Capacity (AWC) – the difference between field capacity and permanent wilting point.

Readily Available Water (RAW) – a more specific indicator than AWC, referring to water that is *readily available* to the vine. This is the water held between FC and a pre-determined refill point. The refill point for readily available water is considered to be between -40 to -60kPa. RAW values can be calculated using soil texture constants and depths of each horizon in the profile. When utilising regulated deficit irrigation (RDI) the grower will allow the soil to reach higher tension levels at key stages to impose a degree of water stress.

Deficit Available Water (DAW) - when some water is still available to the grapevine, but it requires considerably more energy to extract. DAW is commonly used in regulated deficit irrigation of red varieties to restrain vegetative growth at key phenological stages and subsequently increase fruit quality. DAW describes the part of the soil profile that is "dry" in RDI programs. It occurs when gypsum blocks have readings between -100 and -400kPa, depending on soil type/texture.

Figure 2. Relationship between soil moisture tension (-kPa) and available soil water.

Field Capacity	Readily Available Water (RAW)	Deficit Available Water (DAW)	Permanent Wilting Point (PWP)
0 -2 to -8	-40 to -60	-100 to -400	-1500
Wet	Moist	Dry	Very Dry

SOIL CHEMICAL PROPERTIES

Cation exchange capacity (CEC)

The most common exchangeable cations (positively charged atoms) in the soil are calcium (Ca^{2+}), potassium (K^{+}), magnesium (Mg^{2+}) and sodium (Na^{+}).
The cation exchange capacity of a soil is a quantitative measure of the soil's ability to hold exchangeable cations, indirectly indicating the negative charge present per unit mass of soil. CEC varies with clay and organic matter content, as the surfaces of these materials are usually negatively charged. These cations are termed 'exchangeable' because they can be displaced by other cations.
Alkaline soils generally have high CEC measurements while acidic soils are lower due to the displacement of exchangeable cations by hydrogen (H^{+}) and aluminium (Al^{3+}). From a practical viewpoint, the main reason for measuring CEC in vineyard soils is to evaluate the potential fertility of the soil; the higher the CEC the more fertile the soil is likely to be.

Table 5. Ratings for exchangeable cations (Nicholas, 2004).

CEC (cmol(+)/kg soil)	Low	Medium	High
Total cations extracted from soil solution (measured)	<5	5-15	>15
Sum of the basic cations	<3	3-10	>10

Soil pH

Nicholas (2004) describes the most suitable vineyard soils as having a pH of between 5.0 and 8.5 in the rootzone and between 5 and 7.5 in the topsoil. Soil pH is a measurement of the relative concentrations of hydrogen (H^{+}) and hydroxyl (OH^{-}) ions in the soil. Neutral soils contain equal concentrations of H^{+} and OH^{-}, acid soils have a higher proportion of H^{+}, and alkaline soils have a higher proportion of OH^{-}. Because H^{+} is an exchangeable cation, soil pH is influenced by the cation exchange capacity, which in turn pH affects nutrient availability to the plant.
Soil pH is also influenced by organic matter, high rainfall (>500mm), parent material, and management practices.

Acid soils (pH < 5.0) – soils become acidified under conditions of high rainfall and heavy leaching. High root mass and large amounts of organic matter also have an acidifying effect on the soil (Nicholas, 2004). The application of urea and ammonium fertilizers in excess of plant requirements often causes a decrease in pH, as negatively charged nitrate ions leach through the profile and displace exchangeable cations. These become replaced by hydrogen ions.
Acid soils can cause phosphorus, potassium, sulphur, calcium and magnesium deficiencies and aluminium and manganese toxicity.

Alkaline soils (pH > 7.5) – usually found in low rainfall areas and soils with bicarbonate and carbonate salts. Deficiencies in iron, manganese and zinc are common in alkaline soils where the surface soil is calcareous.

Soil pH is can measured in water or calcium chloride, both in a soil to solution ratio of 1:5. In the pH range of 4-5, the calcium chloride reading is approximately 0.8 units lower.

Salinity

Soils are classified as saline when the electrical conductivity of a saturated soil extract is greater than 4 dS/m (McLaren and Cameron, 1996). Grapevines become negatively affected by saline soils because of a reduction in osmotic water potential which lowers the amount of readily available water.

Table 6. Guidelines for interpreting salinity data on the suitability of vineyard soils (adapted from Nicholas, 2004, after Peacock and Christensen, 2000).

	No problem	Increasing problem	Severe problem
Salinity (EC dS/M)	< 2.5	2.5 - 4	> 4

Sodicity

Soils become sodic when high sodium content displaces exchangeable calcium and magnesium. The main influence of sodicity is a loss in soil structure (friability and permeability), leading to problems such as hard setting, compaction and waterlogging. The sodicity index used in this profile is the *sodium adsorption ratio* (SAR) which is the relative concentration of sodium to calcium and magnesium in soil solution.

Table 7. Critical limits for soil degradation due to sodicity (for pedal and clayey soils), (adapted from Nicholas, 2004).

Soil micro-structure stability	Non sodic	Sodic	Highly sodic
SAR	0 - 3	3 - 7	> 7

Nutrients

There is a proliferation of literature regarding soil nutrients and fertilization methodologies. For further reading see Nicholas (2004), White (2003), Coombe and Dry (1988), and McLaren and Cameron (1996). For the purpose of this profile, reference information on desired soil nutrient levels will be provided as a basis for comparison to the soil types covered. However, it must be recognized that there is no direct correlation between soil

nutrient status and the nutrient status of the vine. This is due to the complex nature of soil reactions which bind and release compounds under varying conditions, altering their availability to the vine. Thus, it is advisable to use both plant and soil analysis when making decisions on vineyard nutrition requirements.

Table 8. Soil test standards (adapted from Research to Practice® – Grapevine Nutrition Manual. Cooperative Research Centre for Viticulture, 2005).

Element or Test	Expressed as	Topsoil sample	Subsoil sample
MICRONUTRIENTS		Soil tests for many micronutrients are not well calibrated for grapevines. Note that there are a number of different testing procedures, which extract different amounts of each element.	
Nitrate nitrogen	NO_{3-} *(mg/kg)*	Not particularly useful because the value can change quickly as soil moisture content changes. Nitrate can be quite easily leached from the soil.	Not a particularly useful test as the values can change quickly.
Ammonium nitrogen	NH_{4+} *(mg/kg)*	Not a particularly useful test. Similar reasons to nitrate nitrogen.	
Colwell Bicarbonate extractable Phosphorus (16 h shake)	*P (mg/kg)*	30mg/kg is sufficient for a pasture or crop (mid row area). Aim for more like a vegetable concentration in the under vine bank (60-80mg/kg). In vineyards where superphosphate has been ripped in, levels in the topsoil may apparently be low, but the vine may find sufficient phosphorus from deeper in the soil profile.	No standards for subsoil P as the vines get most of their needs from the topsoil. If a ripper has been used to apply P at depth, concentrations around 80-100mg/kg can be found in the band.
Colwell Potassium	*K (mg/kg)*	Values above about 100mg/kg are often sufficient for mature vines, but may not be for vine establishment. Above about 250mg/kg extractable K is abundant.	Often K levels in the subsoil clays are higher than in the topsoil due to a higher concentration of clay, and this is where the vines get their K. Expect values in the range 150-250mg/kg.
Extractable Sulphur	*S (mg/kg)*	No standards available. Levels less than 10mg/kg may warrant treatment in vineyards that are being established. In vineyards that receive sulphur as a disease management treatment, it is unlikely to be in short supply.	
DPTA Extractable Copper	*Cu (mg/kg)*	Low is considered to be less than about 0.3mg/kg. Copper levels in established vineyard soils are often much higher than this as a consequence of copper sprays used in disease management. Toxic values are set as low as 2mg/kg but if above 10-20mg/kg care should be taken to keep the pH of the soil near neutral.	
DPTA Extractable Iron	*Fe (mg/kg)*	Above about 0.2mg/kg no problems are expected, but values are usually much higher than this. pH, presence of free lime and waterlogging can all reduce the availability of the iron in the soil to the vines' roots irrespective of the soil test value. Not particularly useful.	
Reactive Iron	*Fe (ppm)*	This is a test that is not well understood. Gives a rough indication of how likely the soil is to fix applied phosphorus fertiliser in an unavailable form.	

DPTA Extractable Manganese	*Mn (mg/kg)*	Low is considered to be below about 4mg/kg. Mn can be bound to soil particles in alkaline soils. In acid soils it becomes more available, and in waterlogged soils may be found at toxic levels.
DPTA Extractable Zinc	*Zn (mg/kg)*	Low is considered to be less than about 2mg/kg in acid or neutral soils. Less than 0.8 in alkaline soils may not cause problems but these values are not extremely useful. In areas with alkaline soils use of foliar zinc is prudent no matter what the soil zinc level. Petiole tests can help to confirm a need for amelioration. Zinc toxicity in vines is rarely documented, but a high value might be above 20mg/kg.
Exchangeable Calcium	*Ca (meq/100 g)*	A calcium to magnesium ratio of about 1:1 or less can be associated with structural instability if the soil is sodic. (See Exchangeable Sodium Percentage).
Exchangeable Sodium	*Na (meq/100 g)*	See Exchangeable Sodium Percentage.
Exchangeable sodium percentage	*Exchangeable sodium/CEC x 100*	Exchangeable sodium percentage (ESP) values less than 6 should not present problems. In the US a sodic soil is one that has 15% ESP. In Australia an ESP of 6 is often classified as sodic. Clay particles in sodic soils can disperse and diminish soil structure. This tendency can be confirmed with a slaking and dispersion test in the laboratory.
Exchangeable Aluminium	*Al (mg/kg)*	If exchangeable aluminium is present it is an indicator that the soil is too acid and should be limed, particularly if a vineyard is to be established. Free aluminium is toxic to roots and is a part cause of poor root growth in acid soil conditions.
Extractable Aluminium	*Al calcium chloride extract (mg/kg)*	If extractable aluminium is present it is an indicator that the soil is too acid and should be limed, particularly if a vineyard is to be established. Free aluminium is toxic to roots and is a part cause of poor root growth in acid soil conditions.
Extractable Boron	*B (mg/kg)*	0.5-1.0mg/kg seems fine for vines. Care should be taken if the B in the root zone increases above about 2mg/kg as it is toxic at these levels.

Organic matter

Soil organic matter has many beneficial impacts on soil quality:

1. Increases cation exchange capacity, making nutrients more plant-available.
2. Supplies nutrients via the decomposition of humus.
3. Releases nutrients from minerals via the action of acidic organic compounds.
4. Provides a food source for the soil microbial population, and other living organisms (i.e. earth worms).
5. Improves soil structure.
6. Improves available water holding capacity of the soil.
7. Improves drainage.
8. Increases heat absorption via dark colouration of surface soil.
9. Aids in deactivation of vineyard chemicals, such as herbicides.

Soil organic matter (SOM) is measured in relationship with soil organic carbon (SOC) values, using the following conversion:
SOM (%) = SOC (%) x 1.75.
Optimal SOM values are between 3.5 – 5.25%
Optimal SOC values are between 2 – 3%

Chemical Barriers

Chemical barriers are those that cause restricted root growth, due to soil pH or toxicity caused by high levels of certain compounds.

Table 9. Assessment of potential chemical barriers (Neja et al, 1974).

Type of Barrier	No problem	Increasing problem	Severe problem
Alkalinity (pH in water)	< 8.5	8.5 - 9.2	> 9.2
Acidity (pH in $CaCl_{2)}$	> 5.0	4.2 - 5.0	< 4.2
Sodium toxicity (ESP)	< 13	13 - 25	> 25
Boron (mg/kg)	< 1	1 - 3	> 3
Chloride (mg/kg)	< 350	350 - 1060	> 1060

Margaret River regional soil types

The following information summarizes the types of soils that are found in the Margaret River wine region. Local names have been used to ensure the profile is user-friendly. The photographs are representations of the respective soil types and do not account for the large degree of variation in soil characteristics observed throughout the region.

SOIL TYPE	Estimated % soil under vines[3]
Forrest Grove soils	
Forest Grove gravelly sand	35%
Forest Grove sandy clay loam	5%
Forest Grove sand	3%
Forest Grove shallow gravel	2%
Forest Grove total	**45%**
Mungite soils	
Mungite sandy clay loam	1%
Gravelly Mungite sandy loam	4%
Mungite deep sand	4%
Mungite sand and yellow-brown sand	12%
Mungite total	**21%**
Marybrook soils	
Marybrook red loam, red-brown sandy and yellow sandy loams	5%
Marybrook grey sandy loam	3%
Marybrook red sand	1%
Marybrook red-brown clay	0%
Marybrook total	**9%**
Keenan soils	
Keenan loam, sandy clay loam and colluvium	3%
Keenan stony duplex	1%
Keenan total	**4%**
Other soils	
Bleached sand and gravelly sand	5%
Wet sands and other wet soils	3%
Yellow sands/Spearwood Sands	2%
Busselton soils	3%
Abba soils	1%
Shallow sands	1%
Other total	**15%**
TOTAL	**94%**

[3] This data has been sourced from the Department of Agriculture and Food. It should be noted that the percentages are general estimates only based on the typical distribution of soil types within map units planted to vines. Within the map units it is likely that certain soil types are more favoured by viticulturalists than others.

Soil Type Profiles

In most cases pit locations were selected on the basis of a survey in which growers identified the major soil types on their property. Where certain soil types were not described, land systems data was used to determine potential locations under winegrape production.

Profiling a particular soil type presents numerous challenges. The continuous nature of soil medium, with indistinct physical boundaries compared to plant or animal species, makes distinct categorisation of soils difficult. At the same time, the composition and properties of soils are not fixed and can easily vary with changes in hydrology, crops and vegetations, land use and management practices, resulting in high soil variability even within a small locality. The soil profiles described in this report were all located within vineyard blocks and have been influenced by the individual soil management techniques employed. As such the nutritional status of each pit cannot represent all soils of their type. Therefore the soil pits used in this report are more of a reference than a standard. A GPS pit location was collected (GPS data is not included in this report but is available for some sites on request).

Chemical Analysis methods:

The main soil test used was the Mehlich-3 procedure, a rapid multi-element soil test developed in the USA in the 1980's that has been validated for West Australian soils. The method involves mixing extractants with soil and then analysing the sample with an *Inductively Coupled Plasma Atomic Emission Spectrometer* (ICP-AES) to determine what elements are present. It measures available P, K, S, Ca, Mg, Na, S, Cu, Fe, Mn, B, Mo and Zn. Work done by the WA Chemistry Centre has shown that results obtained from the Mehlich 3 extractant are consistent with other single-element soil tests used over a range of soil types found in WA. The test performs particularly well in acidic and neutral soils, which make up the majority of our surface soils.

Other methods:

- For explanations of soil test standards and optimal nutrient levels, please refer to Table 8.
- The measuring stick used in the soil profile photographs alternates colour with every 100mm increment.
- RAW for each soil pit was calculated using data from Wetherby 1998 with the RAW for course sand set at 19mm/m as per van Gool *et al*, 2004 to take into account the low water holding capacity of coarse sand found in Western Australia.

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Soil Type 1: Forrest Grove Gravelly Sand

Profile

Soil group of Western Australia (Schoknecht 2002): Loamy gravel/Duplex sandy gravel. Approximately 50 cm of a gravelly, yellow brown sand or sandy loam topsoil overlying a yellow brown sandy clay loam to sandy clay subsoil.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	12	0	12	Dark brown sandy loam
A3	30	12	42	Light brown sandy loam with approx. 40% ironstone pea gravel
B1	20	42	62	Yellow brown sandy clay loam with approx. 60% gravel and quartz grit
B2/C	55	62	117	White sandy clay with moderate iron oxide and 10% gravel/laterite rock
C		117		indurated clay over sheet laterite



Drainage

Moderately well to imperfectly drained. Topsoil well drained due to sandy loam texture. Clay subsoil may cause drainage problems on flat areas and lateral movement of water on slopes. This soil types is usually found on slopes.

Potential root zone 117 cm in sampling pit.

Barriers to root growth

Depth to poorly structured clay and occasionally sheet laterite will determine rooting depth. However, grapevines have been observed to grow into ironstone layers via cracks and

fissures.

Water holding capacity

Readily available water 53mm

Fertility

Moderate to low inherent fertility due to high sand content throughout profile. Phosphorus retention is often high due to the presence of ironstone. Low cation exchange capacity.

Erosion potential

High erosion potential on slopes due to sandy texture. Fine topsoil is prone to wind erosion when left bare and unprotected but often protected by the presence of gravel.

Soil pit analysis

Horizon	A1	A2	B1	B2
EC (1:5) (mS/m)	9	3	2	9
pH (CaCl2)	6.3	5.3	5.4	4.3
Organic Carbon (W/B) %	2.39	0.68	0.3	0.14
Macro elements				
Nitrate $N0_3$ (mg/kg)	25	3	1	1
Phosphorus (mg/kg)	>250	21	2	<1
Potassium (mg/kg)	65	19	23	11
Sulphur (mg/kg)	17	12	17	240
Calcium (mg/kg)	1800	240	140	78
Magnesium (mg/kg)	140	32	57	150
Micro elements				
Boron (mg/kg)	0.6	0.2	0.2	0.3
Copper (mg/kg)	8.9	1.1	0.3	0.1
Iron (mg/kg)	230	120	51	44
Manganese (mg/kg)	21	8	<1	<1
Molybdenum (mg/kg)	0.01	0.01	<0.01	<0.01
Zinc (mg/kg)	3.7	0.5	0.1	<0.1
Exchangeable cations				
Calcium (cmol(+)/kg)	9	1.2	0.7	0.39
Magnesium (cmol(+)/kg)	1.2	0.3	0.5	1.2
Potassium (cmol(+)/kg)	0.2	0.0	0.1	0.0
Sodium (cmol(+)/kg)	0.1	0.0	0.0	0.3
Cation exchange capacity				
CEC (cmol(+)/kg)	10.4	1.5	1.2	2.0

Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 2: Forrest Grove Shallow Gravel

Profile

Soil group of Western Australia (Schoknecht 2002): Shallow gravel - gravelly yellow brown sand or sandy loam overlying sheet laterite.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	15	0	15	Dark brown sandy loam with 5% ironstone pea gravel and smooth-faced stone
B1	40	15	55	Light yellow brown sandy clay loam with 40% ironstone pea gravel and smooth-faced stone
B2	55	55	110	Indurated white sandy clay with 50% round-faced ironstone (10-60mm)
C		110		Sheet laterite



Drainage

Moderately well to imperfectly drained. Topsoil is free draining due to sandy loam texture but clay subsoil and underlying sheet laterite may cause drainage problems on flat areas.

Potential root zone 55 cm in sampling pit.

Barriers to root growth

Shallow soil. Root growth is moderately restricted by subsoil clay and restricted by sheet laterite. However, grapevines have been observed to grow into ironstone layers via cracks and fissures.

Water holding capacity

Readily available water 42mm

Fertility

Shallow rooting depth results in less available nutrients per volume of soil. However, clay subsoil has a higher concentration of exchangeable cations than other Forest Grove soils. Phosphorus retention increases with ironstone content.

Erosion potential

Moderate to high risk of wind erosion of the topsoil when unprotected and bare but often protected by the presence of gravel. Low potential for water erosion on flats but moderate risk on slopes due to the erodibility of the surface soil.

Soil pit analysis

Horizon	A1	B1	B2
EC (1:5) (mS/m)	19	7	7
pH (CaCl2)	5.5	5.6	5.7
Organic Carbon (W/B) %	3.57	0.74	0.28
Macro elements			
Nitrate $N0_3$ (mg/kg)	86	3	1
Phosphorus (mg/kg)	20	2	1
Potassium (mg/kg)	220	270	200
Sulphur (mg/kg)	14	47	130
Calcium (mg/kg)	1500	340	200
Magnesium (mg/kg)	340	200	190
Micro elements			
Boron (mg/kg)	0.4	0.7	0.4
Copper (mg/kg)	1.6	0.2	0.1
Iron (mg/kg)	120	49	50
Manganese (mg/kg)	39	2	2
Molybdenum (mg/kg)	0.01	0.02	<0.01
Zinc (mg/kg)	1.5	0.1	0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	7.5	1.7	1
Magnesium (cmol(+)/kg)	2.8	1.6	1.6
Potassium (cmol(+)/kg)	0.6	0.7	0.5
Sodium (cmol(+)/kg)	0.2	0.2	0.2
Cation exchange capacity			
CEC (cmol(+)/kg)	11.0	4.2	3.2

Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 3: Forrest Grove Sand

Profile

Soil group of Western Australia (Schoknecht 2002): Yellow-brown deep sandy duplex - approximately 50 cm of a yellow brown sand or sandy loam topsoil overlying a yellow brown sandy clay loam to sandy clay subsoil.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	15	0	15	Brown sandy loam
A3	35	15	50	Yellow brown sand. 5% ironstone gravel
B	60	50	110	Yellow brown sandy clay loam with 70% ironstone gravel 3-100mm
B/C	55	110	165	White medium sandy clay with 5% ironstone pea gravel and orange oxidation



Drainage

A relatively deep, well drained soil due to the high sand content throughout the profile.

Potential root zone 165 cm in sampling pit.

Barriers to root growth
None. Roots were observed at pit base.

Water holding capacity
Readily available water 64mm

Fertility
The low clay content in the topsoil restricts the capacity of the soil to retain nutrients in the zone where uptake is greatest. The presence of ironstone gravel increases phosphorus retention.

Erosion potential
High water erosion potential on slopes. High wind erosion risk when soil is unprotected and bare due to the texture of the light surface soil.

Soil pit analysis

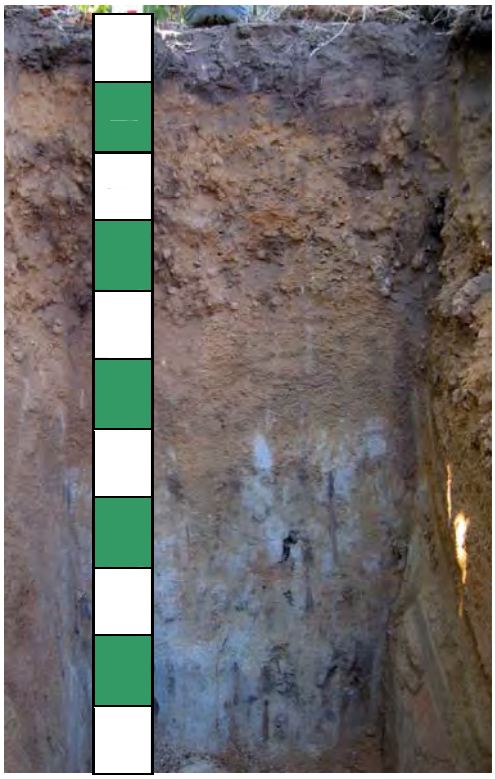
Horizon	A1	A3	B	B/C
EC (1:5) (mS/m)	12	2	2	3
pH (CaCl2)	5.6	5.5	5.7	6.1
Organic Carbon (W/B) %	1.53	0.32	0.18	0.2
Macro elements				
Nitrate $N0_3$ (mg/kg)	50	2	1	1
Phosphorus (mg/kg)	73	3	2	1
Potassium (mg/kg)	29	44	17	25
Sulphur (mg/kg)	6	6	10	80
Calcium (mg/kg)	500	120	81	220
Magnesium (mg/kg)	68	28	31	160
Micro elements				
Boron (mg/kg)	<0.1	<0.1	<0.1	0.2
Copper (mg/kg)	1.7	0.1	0.1	0.1
Iron (mg/kg)	52	41	28	34
Manganese (mg/kg)	25	5	1	1
Molybdenum (mg/kg)	<0.01	<0.01	<0.01	<0.01
Zinc (mg/kg)	1.2	0.1	0.1	0.1
Exchangeable cations				
Calcium (cmol(+)/kg)	2.5	0.6	0.405	1.1
Magnesium (cmol(+)/kg)	0.6	0.2	0.3	1.3
Potassium (cmol(+)/kg)	0.1	0.1	0.0	0.1
Sodium (cmol(+)/kg)	0.0	0.0	0.0	0.1
Cation exchange capacity				
CEC (cmol(+)/kg)	3.2	1.0	0.7	2.5

Soil type regional map
See Appendix A for a location map of these soils.

Soil Type 4: Forrest Grove Sandy Clay/Sandy Clay Loam

Profile

Soil group of Western Australia (Schoknecht 2002): Loamy gravel/Brown deep loamy duplex - a brown, gravelly sandy clay loam overlying sandy clay.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	7	0	7	Brown loam
A3	30	7	37	Yellow brown sandy loam with 40% ironstone pea gravel
B1	20	37	57	Yellow brown sandy clay loam with 25% ironstone gravel
B2/C	53	57	110	Pale sandy clay with 60% oxidised ironstone fragments



Drainage

A moderately deep, well drained soil due to the prevalence of sand in the topsoil and the sandy clay subsoil.

Potential root zone 110 cm in sampling pit.

Barriers to root growth

Clay subsoil may form a barrier to roots

Water holding capacity

Readily available water 40mm

Fertility

Low inherent fertility. Phosphorus retention remains a problem due to ironstone gravel content. Low cation exchange capacity.

Erosion potential

A slightly heavier topsoil than previous Forest Grove types, therefore less erosion potential.

Soil pit analysis

Horizon	A1	A3	B1	B2/C
EC (1:5) (mS/m)	11	3	2	2
pH (CaCl2)	5.2	4.4	5	4.8
Organic Carbon (W/B) %	5.62	0.32	0.17	0.28
Macro elements				
Nitrate $N0_3$ (mg/kg)	21	3	N/A	1
Phosphorus (mg/kg)	140	7	N/A	9
Potassium (mg/kg)	100	17	N/A	3
Sulphur (mg/kg)	20	20	N/A	70
Calcium (mg/kg)	1600	70	N/A	140
Magnesium (mg/kg)	96	8	N/A	32
Micro elements				
Boron (mg/kg)	<0.1	<0.1	N/A	<0.1
Copper (mg/kg)	1.6	0.5	N/A	0.5
Iron (mg/kg)	100	40	N/A	33
Manganese (mg/kg)	7	<1	N/A	1
Molybdenum (mg/kg)	<0.01	<0.01	N/A	<0.01
Zinc (mg/kg)	5.8	0.2	N/A	0.3
Exchangeable cations				
Calcium (cmol(+)/kg)	8	0.35	N/A	0.7
Magnesium (cmol(+)/kg)	0.8	0.1	N/A	0.3
Potassium (cmol(+)/kg)	0.3	0.1	N/A	0.1
Sodium (cmol(+)/kg)	0.1	0.1	N/A	0.1
Cation exchange capacity				
CEC (cmol(+)/kg)	9.1	0.6	N/A	1.1

Soil type regional map

See Appendix A for a location map of these soils.

MANAGEMENT ISSUES - FOREST GROVE SOILS

Vine Performance: These soils allow well-balanced vine growth that is not overly vigorous due to low fertility and low to moderate available water. Of all the regional soil types, these have the highest proportion of area under vine (45%), and are considered as highly suitable vineyard soils. Whilst they are suitable for most varieties high quality Cabernet and Chardonnay are produced on these soils types. Waterlogging is generally not a problem due to their prevalence on slopes. They generally achieve good heat retention due to a high gravel content.

Irrigation practices: Forrest Grove soils have low to moderate water holding capacity. With the exception of the shallow gravel, these soils types are relatively deep allowing vines to access water but not excessive amounts. Although the topsoil is well drained the profile rarely completely dries out due to the friable clay subsoil which supplies deficit available water. The sandier types respond quickly to water application and it is relatively easy to maintain moisture levels. A range of different irrigation practices are successful on these soil types. Dryland production is viable on deeper loamy types with a friable clay subsoil due to the accessibility of water reserves in the subsoil, however low yields result.

Nutrition and soil amendments: Lime is generally required to correct low pH levels. Phosphorous requirement in establishment is high due to the high P fixing of these soils and a phosphorus maintenance program is required to maintain available phosphorous. These soils respond well to nutrition and will benefit from treatments that increase organic matter. The percentage of gravel reduces the total soil volume capable of supplying nutrients.

Vineyard floor management: Generally need to improve organic matter content on lighter textured soils. The deeper phases have low water holding capacities and annuals don’t persist well.

Other issues: Sheet laterite undulates within the profile and sometimes appears at the surface, thereby presenting a challenge for soil preparation and vineyard development. A large amount of rock removal is often required during and after deep ripping and may remain a problem during trellis installation.

Soil Type 5: Marybrook Red Brown Sandy Loam

Profile

Soil group of Western Australia (Schoknecht 2002): Friable red-brown loamy earth - a red brown sandy loam, with a brown surface, grading into an earthy red brown sandy clay loam.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	30	0	30	Dark brown loam
A2	20	30	50	Red brown loam interspersed with grey sand
A3	30	50	80	Red brown sandy loam with 12% gravel
B	40	80	120	Orange sandy clay loam
C	45	120	165	Orange brown sandy clay



Drainage

A well drained, deep soil.

Potential root zone 165 cm in sampling pit.

Barriers to root growth

None.

Water holding capacity

Readily available water 112mm

Fertility

Moderate inherent fertility. Iron content has the potential to increase the phosphorus retention.

Erosion potential

Erosion is not a high risk as these soils are predominately located in flat areas.

Soil pit analysis

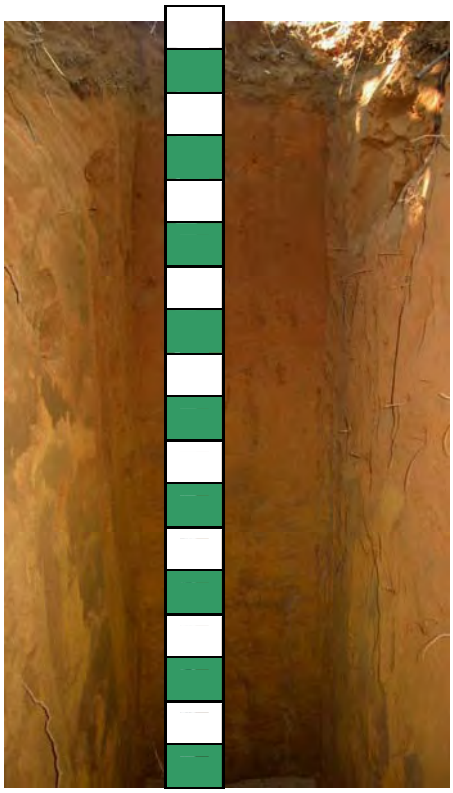
Horizon	A1	A2	A3	B	C
EC (1:5) (mS/m)	6	4	3	3	2
pH (CaCl2)	6.6	4.6	4.9	5.2	5.5
Organic Carbon (W/B) %	2.14	2.04	1.08	0.33	0.24
Macro elements					
Nitrate $N0_3$ (mg/kg)	13	6	2	1	1
Phosphorus (mg/kg)	120	10	9	5	3
Potassium (mg/kg)	47	67	27	7	24
Sulphur (mg/kg)	16	17	33	29	13
Calcium (mg/kg)	2000	540	230	130	190
Magnesium (mg/kg)	110	63	27	26	18
Micro elements					
Boron (mg/kg)	0.4	0.3	<0.1	<0.1	<0.1
Copper (mg/kg)	1.3	0.1	<0.1	<0.1	<0.1
Iron (mg/kg)	78	370	130	120	46
Manganese (mg/kg)	6	1	<1	<1	<1
Molybdenum (mg/kg)	<0.01	<0.01	<0.01	0.01	<0.01
Zinc (mg/kg)	1.6	0.3	<0.1	<0.1	<0.1
Exchangeable cations					
Calcium (cmol(+)/kg)	10	2.7	1.15	0.65	0.95
Magnesium (cmol(+)/kg)	0.9	0.5	0.2	0.2	0.1
Potassium (cmol(+)/kg)	0.1	0.2	0.1	0.0	0.1
Sodium (cmol(+)/kg)	0.0	0.1	0.0	0.0	0.1
Cation exchange capacity					
CEC (cmol(+)/kg)	11.1	3.4	1.5	0.9	1.3

Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 6: Marybrook Red Sand

Profile
Soil group of Western Australia (Schoknecht 2002): Red deep sand/Red sandy earth - a reddish sand or clayey sand over a metre deep grading into a reddish sandy loam.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	25	0	25	Dark brown sandy loam
A3	85	25	110	Red brown sand
A4	50	110	160	Red/orange sand
B	20	160	180	Orange brown clayey sand



Drainage
A very deep, well drained soil.

Potential root zone 180 cm in sampling pit.

Barriers to root growth
None

Water holding capacity

Readily available water 78mm

Fertility
Moderate fertility, with lower cation exchange capacity than other Marybrook soil types.

Erosion potential
Sandy topsoil subject to wind erosion if disturbed.

Soil pit analysis

Horizon	A1	A3	A4	B
EC (1:5) (mS/m)	7	2	3	3
pH (CaCl2)	7.1	6	6.1	6.3
Organic Carbon (W/B) %	1.6	0.46	0.21	0.16
Macro elements				
Nitrate $N0_3$ (mg/kg)	4	1	1	1
Phosphorus (mg/kg)	100	2	1	1
Potassium (mg/kg)	49	61	31	64
Sulphur (mg/kg)	10	6	34	26
Calcium (mg/kg)	2100	140	140	200
Magnesium (mg/kg)	130	91	58	68
Micro elements				
Boron (mg/kg)	0.7	0.2	0.3	0.4
Copper (mg/kg)	1.8	<0.1	<0.1	<0.1
Iron (mg/kg)	69	51	26	25
Manganese (mg/kg)	7	8	2	<1
Molybdenum (mg/kg)	0.02	0.01	0.02	0.01
Zinc (mg/kg)	2.6	0.1	<0.1	<0.1
Exchangeable cations				
Calcium (cmol(+)/kg)	10.5	0.7	0.7	1
Magnesium (cmol(+)/kg)	1.1	0.7	0.5	0.6
Potassium (cmol(+)/kg)	0.1	0.2	0.1	0.2
Sodium (cmol(+)/kg)	0.1	0.0	0.1	0.1
Cation exchange capacity				
CEC (cmol(+)/kg)	11.8	1.6	1.3	1.8

Soil type regional map
See Appendix A for a location map of these soils.

Soil Type 7: Marybrook Red Loam

Profile

Soil group of Western Australia (Schoknecht 2002): Friable red-brown loamy earth - an earthy red loam, with a friable brown surface, grading into a sandy clay loam or light clay.

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Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	15	0	15	Reddish brown friable loam with 60% gravel
B1	65	15	80	Red loam with 20% gravel
B2	85	80	165	Light orange brown sandy clay loam



Drainage

A deep, well drained soil.

Potential root zone 165 cm in sampling pit.

Barriers to root growth

None.

Water holding capacity

Readily available water 70mm

Fertility
Higher nutrient retention than other Marybrook soil types due to the soil texture.

Erosion potential
Low risk.

Soil pit analysis

Horizon	A1	B1	B2
EC (1:5) (mS/m)	13	12	22
pH (CaCl2)	6.3	6.2	6.4
Organic Carbon (W/B) %	2.08	1.03	0.24
Macro elements			
Nitrate $N0_3$ (mg/kg)	29	1	1
Phosphorus (mg/kg)	44	<1	<1
Potassium (mg/kg)	260	150	3
Sulphur (mg/kg)	20	47	180
Calcium (mg/kg)	2000	960	190
Magnesium (mg/kg)	190	140	270
Micro elements			
Boron (mg/kg)	0.8	2.4	2.1
Copper (mg/kg)	2.5	<0.1	<0.1
Iron (mg/kg)	83	25	52
Manganese (mg/kg)	11	2	1
Molybdenum (mg/kg)	0.01	<0.01	<0.01
Zinc (mg/kg)	1.4	<0.1	<0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	10	4.8	0.95
Magnesium (cmol(+)/kg)	1.6	1.2	2.2
Potassium (cmol(+)/kg)	0.7	0.4	0.0
Sodium (cmol(+)/kg)	0.1	0.3	0.9
Cation exchange capacity			
CEC (cmol(+)/kg)	12.4	6.7	4.1

Soil type regional map
See Appendix A for a location map of these soils.

Other Marybrook Soils

There are three other soil types classified as Marybrook soils which were not described and analysed, as soil profiles matching their descriptions were not found during the survey process.

Soil Type 8

Soil group of Western Australia (Schoknecht 2002): Marybrook Yellow Sandy Loam - Brown loamy earth - a brown earthy sandy loam, with a friable surface, grading into a yellow sandy clay loam at about 50 cm.

Soil Type 9

Soil group of Western Australia (Schoknecht 2002): Marybrook Grey Sandy Loam - Semi-wet soil/Pale loamy earth - a fine grained sandy loam grading into a sandy clay loam or sandy clay.

Soil Type 10

Soil group of Western Australia (Schoknecht 2002): Marybrook Red Brown Clay - Red loamy earth/Red non-cracking clay - a red brown light to medium clay.

MANAGEMENT ISSUES – MARYBROOK SOILS

Vine Performance: These soils often promote vigorous vine growth due to the large potential rooting volume and available water. They are capable of producing large canopies and high yields with the correct trellis system. These soils are mainly located in warmer northern areas of the region and are adaptable to many varieties. They may not be suitable when aiming to produce small berries on red varieties due to high vigour early in the season. Disease pressure can be high due to canopy size and density.

Irrigation practices: These soils are generally deep and have a relatively high water holding capacity. Imposing regulated deficit irrigation deficit irrigation is difficult in these soils in spring due to high water holding capacities. Vines growing on these soils respond well to drip irrigation.

Nutrition and soil amendments: These soils have a good natural fertility. However, annual phosphorus inputs are often required due to the iron content in the soil. They are often slightly acidic and pH may need to be amended with lime.

Vineyard floor management: These soils are highly trafficable and are generally easy to establish cover crops. Topsoil compaction on land used for vegetable cropping may necessitate ripping before planting.

Soil Type 11: Mungite Sand

Profile

Soil group of Western Australia (Schoknecht 2002): Semi wet soil/Grey deep sandy duplex/Pale loamy earth. Pale grey brown sand or sandy loam topsoil, with brownish surface, overlying a mottled light grey or white sandy clay loam to sandy clay subsoil. There is an additional Mungite soil type classified as “deep sand”, which has the same characteristics as Mungite sand but to a greater depth.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	28	0	28	Grey brown loamy sand with bleached surface, 40% small gravel
A2	35	28	63	Pale grey brown sandy loam with 10% small gravel
B/C	90	63	153	White sandy clay with moderate orange mottling



Drainage

Imperfectly drained. These soils are seasonally waterlogged, as illustrated by mottling in the subsoil. They remain wet early in the season and become very dry towards the end of the season. The subsoil tends to dry to a hard consistency. They often require subsurface drainage.

Potential root zone 63 cm in sampling pit.

Barriers to root growth

Root growth is restricted by poorly structured clay subsoil. Potential for root rot due to a persistent winter water table early spring. Acidic subsoils may be a barrier.

Water holding capacity

Readily available water 91mm

Fertility

Usually acidic with low inherent fertility and organic matter. Profiles with coarser sand have lower nutrient retention. Low cation exchange capacity in the topsoil, and often highly leached.

Erosion potential

Highly risk of wind and water erosion on slopes. Low water erosion risk and high wind erosion risk on flat areas.

Soil pit analysis

Horizon	A1	A2	B/C
Stones (% of soil volume)	40	17	0
EC (1:5) (mS/m)	4	2	4
pH (CaCl2)	4.3	4.7	5.6
Organic Carbon (W/B) %	1.46	0.28	0.14
Macro elements			
Nitrate $N0_3$ (mg/kg)	7	1	2
Phosphorus (mg/kg)	120	5	1
Potassium (mg/kg)	36	18	8
Sulphur (mg/kg)	24	12	110
Calcium (mg/kg)	140	84	160
Magnesium (mg/kg)	10	14	52
Micro elements			
Boron (mg/kg)	<0.1	<0.1	0.1
Copper (mg/kg)	1.8	0.1	<0.1
Iron (mg/kg)	110	46	17
Manganese (mg/kg)	9	8	<1
Molybdenum (mg/kg)	0.01	<0.01	0.01
Zinc (mg/kg)	1.1	0.1	0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	0.7	0.42	0.8
Magnesium (cmol(+)/kg)	0.1	0.1	0.4
Potassium (cmol(+)/kg)	0.1	0.0	0.0
Sodium (cmol(+)/kg)	0.0	0.0	0.0
Cation exchange capacity			
CEC (cmol(+)/kg)	0.9	0.6	1.3

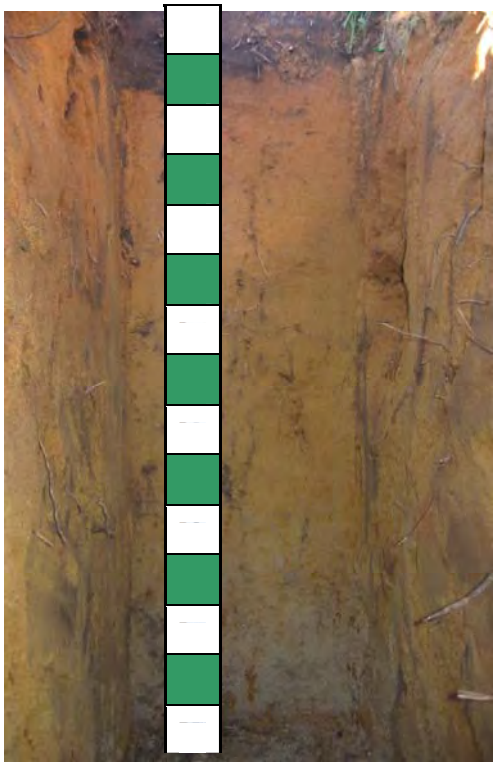
Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 12: Mungite Yellow Brown Sand

Profile

Soil group of Western Australia (Schoknecht 2002): Semi-wet soil/Pale sandy earth - approximately 50 cm of yellow brown sand or sandy loam topsoil, with brownish surface, overlying a mottled light grey or white sandy clay loam to sandy clay subsoil.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	20	0	20	Dark brown sandy loam
A3	35	20	55	Orange brown loamy sand
B	60	55	115	Yellow brown sand
C	30	115	145	Light grey sandy clay with minor orange mottling



Drainage

Moderately to imperfectly drained. Lower risk of waterlogging than other Mungite soil types due to lighter clay subsoil.

Potential root zone 145 cm in sampling pit.

Barriers to root growth

Root growth is generally better than other Mungite soils due to soil depth and texture of

clay. Persistent water table during spring may cause root rot after high rainfall winter periods.

Water holding capacity

Readily available water 71mm

Fertility

Low inherent fertility. However, the colour indicates slightly higher fertility than other Mungite soil types. The finer grain sand results in a higher nutrient holding capacity than other Yellow sands.

Erosion potential

High risk of wind and water erosion on slopes. Low water erosion risk and high wind erosion risk in flat areas.

Soil pit analysis

Horizon	A1	A3	B	C
EC (1:5) (mS/m)	6	2	3	4
pH (CaCl2)	5.9	5	5.2	5.2
Organic Carbon (W/B) %	1.92	0.38	0.14	0.1
Macro elements				
Nitrate $N0_3$ (mg/kg)	20	2	2	1
Phosphorus (mg/kg)	110	3	1	1
Potassium (mg/kg)	76	59	16	27
Sulphur (mg/kg)	16	13	48	93
Calcium (mg/kg)	1000	78	52	78
Magnesium (mg/kg)	110	28	35	60
Micro elements				
Boron (mg/kg)	0.3	<0.1	<0.1	<0.1
Copper (mg/kg)	5.1	0.1	<0.1	0.1
Iron (mg/kg)	73	41	22	32
Manganese (mg/kg)	39	16	<1	<1
Molybdenum (mg/kg)	0.01	<0.01	0.02	<0.01
Zinc (mg/kg)	2.4	0.1	<0.1	<0.1
Exchangeable cations				
Calcium (cmol(+)/kg)	5	0.39	0.26	0.39
Magnesium (cmol(+)/kg)	0.9	0.2	0.3	0.5
Potassium (cmol(+)/kg)	0.2	0.2	0.0	0.1
Sodium (cmol(+)/kg)	0.1	0.0	0.0	0.1
Cation exchange capacity				
CEC (cmol(+)/kg)	6.2	0.8	0.6	1.0

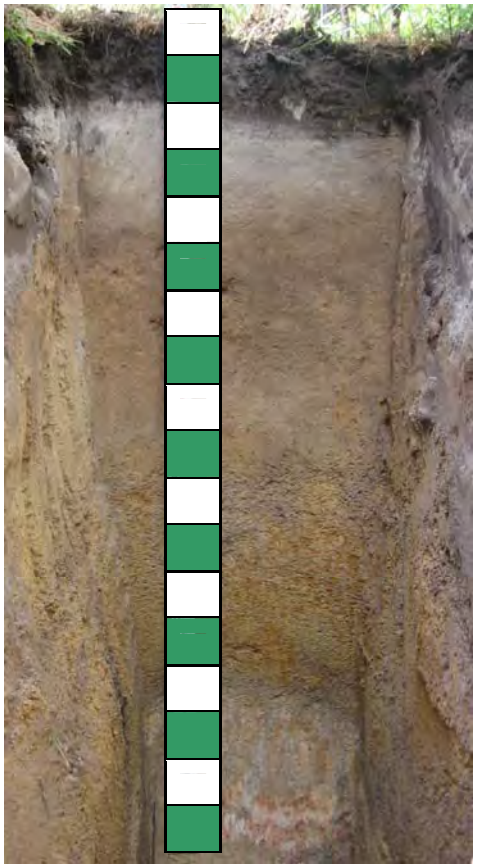
Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 13: Gravelly Mungite Sandy Loam

Profile

Soil group of Western Australia (Schoknecht 2002): Semi-wet soil/Grey deep sandy duplex. Pale grey brown sand or sandy loam topsoil, with brownish surface, overlying a mottled light grey or white sandy clay loam to sandy clay subsoil with greater than 50% ironstone gravel.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	15	0	15	Brown loamy sand with 10% gravel
A2	20	15	35	Pale grey sand
A3	55	35	90	Pale grey brown sand
B1	50	90	140	White sandy clay with heavy orange mottles and 65% ironstone gravel
B2/C	40	140	180	Heavy white clay with orange and red mottling



Drainage

Imperfectly drained. Although gravel may improve water filtration in the B horizon, the heavy clay subsoil impedes drainage. Winter waterlogging and persistently high water table in spring.

Potential root zone 140 cm in sampling pit.

Barriers to root growth

Root growth is restricted by poorly structured subsoil and anaerobic conditions due to persistently high water table in spring.

Water holding capacity

Readily available water 73mm

Fertility

The presence of the pale A2 horizon suggests a high degree of leaching and very low fertility. This soil tends to be slightly acidic. The gravel content increases phosphorus retention.

Erosion potential

High risk of wind and water erosion on slopes. Low water erosion risk and high wind erosion risk in flat areas.

Soil pit analysis

Horizon	A1	A2	A3	B1	B2/C
EC (1:5) (mS/m)	22	1	1	3	5
pH (CaCl2)	6.2	5.1	4.6	5.2	4.2
Organic Carbon (W/B) %	3.26	0.22	0.24	0.21	0.11
Macro elements					
Nitrate $N0_3$ (mg/kg)	66	1	1	1	1
Phosphorus (mg/kg)	>250	8	3	<1	<1
Potassium (mg/kg)	130	0	3	5	8
Sulphur (mg/kg)	36	1	12	97	>250
Calcium (mg/kg)	2900	90	36	160	76
Magnesium (mg/kg)	220	5	4	23	130
Micro elements					
Boron (mg/kg)	0.4	<0.1	<0.1	<0.1	<0.1
Copper (mg/kg)	17	0.2	0.1	0.2	0.2
Iron (mg/kg)	160	31	46	61	36
Manganese (mg/kg)	12	<1	1	2	<1
Molybdenum (mg/kg)	<0.01	<0.01	0.01	<0.01	<0.01
Zinc (mg/kg)	11	0.1	0.3	0.4	<0.1
Exchangeable cations					
Calcium (cmol(+)/kg)	14.5	0.45	0.18	0.8	0.38
Magnesium (cmol(+)/kg)	1.8	0.0	0.0	0.2	1.1
Potassium (cmol(+)/kg)	0.3	0.0	0.0	0.0	0.0
Sodium (cmol(+)/kg)	0.1	0.0	0.0	0.0	0.0
Cation exchange capacity					
CEC (cmol(+)/kg)	16.7	0.5	0.2	1.0	1.5

Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 14: Mungite Sandy Clay Loam

Profile

Soil group of Western Australia (Schoknecht 2002): Semi-wet soil/Pale loamy earth - approximately 50 cm of light grey, light sandy clay loam to sandy clay loam (with brownish surface) overlying a mottled light grey to white sandy clay subsoil.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	10	0	10	Grey brown loamy sand with partially bleached surface and 30% small (1-3mm) gravel
A2	70	10	80	Light grey sandy clay loam
B	40	80	120	White sandy clay with orange mottling



Drainage

Imperfectly drained subsoil with seasonal waterlogging.

Potential root zone 120 cm in sampling pit.

Barriers to root growth

Persistently high water table during early spring may cause root rot of deeper roots.

Water holding capacity

Readily available water 76mm

Fertility

The loam content in this soil generally gives it a slightly higher fertility status than other Mungite soils which are sandier.

Erosion potential

Moderate wind erosion risk. High water erosion risk on slopes due to the light textured surface soil.

Soil pit analysis

Horizon	A1	A2	B
EC (1:5) (mS/m)	23	3	4
pH (CaCl2)	6.2	5	5.4
Organic Carbon (W/B) %	3.54	0.62	0.22
Macro elements			
Nitrate $N0_3$ (mg/kg)	24	2	1
Phosphorus (mg/kg)	>250	7	4
Potassium (mg/kg)	110	24	8
Sulphur (mg/kg)	95	17	110
Calcium (mg/kg)	3200	220	170
Magnesium (mg/kg)	200	35	88
Micro elements			
Boron (mg/kg)	0.1	<0.1	<0.1
Copper (mg/kg)	5.6	0.2	0.2
Iron (mg/kg)	86	56	25
Manganese (mg/kg)	16	1	<1
Molybdenum (mg/kg)	<0.01	<0.01	<0.01
Zinc (mg/kg)	12	0.1	0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	16	1.1	0.85
Magnesium (cmol(+)/kg)	1.6	0.3	0.7
Potassium (cmol(+)/kg)	0.3	0.1	0.0
Sodium (cmol(+)/kg)	0.2	0.0	0.0
Cation exchange capacity			
CEC (cmol(+)/kg)	18.1	1.5	1.6

Soil type regional map

See Appendix A for a location map of these soils.

MANAGEMENT ISSUES – MUNGITE SOILS

Vine Performance: These soils can present vine management difficulties due to often being wet early in the season and very dry later in the season. High vigour early in the season can be a problem on well drained mungite soils. These soils can also be over vigourous due to retained subsoil moisture in some areas. Erratic and uneven budburst can be a problem on wet mungite soils. Reasonable yields can be supported on deeper phases or where drainage has been installed. Where drainage is poor root growth and the long term viability of the vines is impaired. Vineyards with these soil types often require surface and subsurface drainage.

Irrigation practices: The profile tends to be wet early in the season. Late in the season careful water management is required as these soils can be difficult to re-wet once they have dried out. Drip irrigation works effectively on these soils at an emitter spacing that achieve a continuous wetted strip under vine. Soil moisture monitoring is important on these soils to assess sub soil moisture conditions. Imposing regulated deficit irrigation deficit irrigation is difficult in these soils in spring due to high water content.

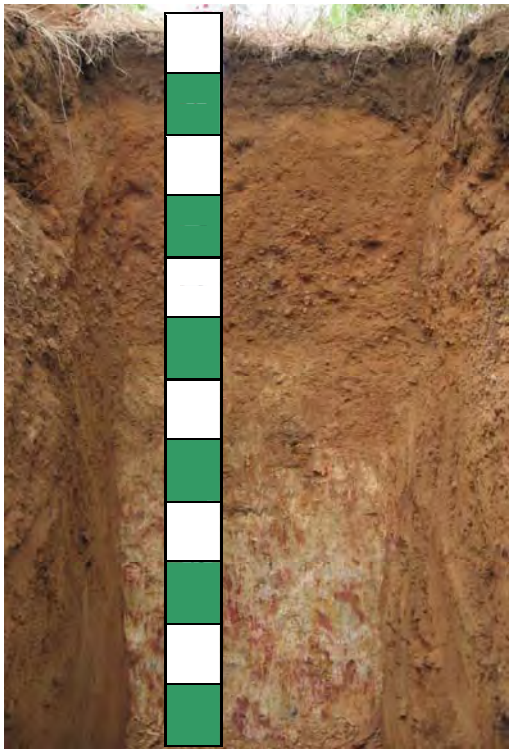
Nutrition and soil amendments: These soils generally have low pH and highly leached A horizons. The timing of deep ripping prior to establishment is critical to ensure good sub soil fracturing and no smearing. Gypsum may improve the structure of the clay subsoil if it is not located too deep. These soils require high nutrient inputs and organic matter additions. Care needs to be taken with additions of mulch where early season soil warmth is required.

Vineyard floor management: The light textured topsoil has poor structure and can be improved with high biomass cover crops, mulches, and compost. Deep rooted, perennial cover crops can be used to reduce excess water in spring and should be mixed with annuals to increase organic matter levels.

Soil Type 15: Keenan Stony Duplex

Profile

Soil group of Western Australia (Schoknecht 2002): Stony soil/Loamy or Sandy duplex - a brownish sand to sandy loam, with dark organic surface, and a clear boundary to a pedal yellow brown sandy clay loam to medium clay containing ironstone gravel and granitic fragments.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	10	0	10	Dark brown sandy loam with 25% ironstone gravel
A3	45	10	55	Yellow brown sandy clay loam with 50% ironstone gravel and quartz grit
B	60	55	115	Medium clay with granitic fragments



Drainage

Moderately well drained, depending on depth to clay. However, drainage is rarely a problem as these soils are generally found on sloping land.

Potential root zone 80 cm in sampling pit.

Barriers to root growth

Poorly structured clay subsoil may restrict root growth if present at less than 50cm depth. Bedrock or gritty saprolite may also be present

Water holding capacity

Readily available water 55mm

Fertility

Moderate inherent fertility. The high percentage of stone/gravel content at the surface which may restrict plant vigour.

Erosion potential

Moderate water erosion risk on slopes when the soil is bare. Low to moderate risk of wind erosion, depending on location.

Soil pit analysis

Horizon	A1	A3	B
Stones (% of soil volume)	24	49	0
EC (1:5) (mS/m)	8	2	5
pH (CaCl2)	6.4	5.8	5.9
Organic Carbon (W/B) %	3.84	0.63	0.27
Macro elements			
Nitrate $N0_3$ (mg/kg)	1	1	1
Phosphorus (mg/kg)	>250	3	1
Potassium (mg/kg)	91	46	57
Sulphur (mg/kg)	20	6	93
Calcium (mg/kg)	3200	290	270
Magnesium (mg/kg)	260	45	280
Micro elements			
Boron (mg/kg)	0.6	<0.1	0.4
Copper (mg/kg)	11	0.1	0.1
Iron (mg/kg)	87	49	46
Manganese (mg/kg)	18	6	<1
Molybdenum (mg/kg)	<0.01	<0.01	<0.01
Zinc (mg/kg)	4.8	<0.1	<0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	16	1.45	1.35
Magnesium (cmol(+)/kg)	2.1	0.4	2.3
Potassium (cmol(+)/kg)	0.2	0.1	0.1
Sodium (cmol(+)/kg)	0.1	0.0	0.1
Cation exchange capacity			
CEC (cmol(+)/kg)	18.5	2.0	3.9

Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 16: Keenan Colluvium

Profile

Soil group of Western Australia (Schoknecht 2002): Friable red-brown loamy earth/Brown loamy earth - a red brown sand to sandy loam, with a dark organic surface, grading into a brownish sandy clay loam to sandy clay with ironstone gravel, quartz pebbles and granitic fragment, as well as granitic boulders present throughout the profile.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	10	0	10	Dark brown sandy loam
A3	60	10	70	Red brown sandy clay loam with 30% mix of ironstone gravel, quartz grit, quartz pebbles. Granite boulders present
B	45	70	115	Yellow brown sandy clay with 30% mix of ironstone gravel and quartz



Drainage

Well drained.

Potential root zone

115 cm in sampling pit.

Barriers to root growth

Granite rock may cause localised restrictions to root penetration.

Water holding capacity

Readily available water 54mm

Fertility

Moderate natural fertility due to loam and clay texture. Slightly acidic.

Erosion potential

Moderate water erosion risk on slopes when the soil is bare. Low to moderate risk of wind erosion, depending on location.

Soil pit analysis

Horizon	A1	A3	B
EC (1:5) (mS/m)	7	4	6
pH (CaCl2)	5.7	6	6.1
Organic Carbon (W/B) %	3.79	0.7	0.27
Macro elements			
Nitrate $N0_3$ (mg/kg)	2	1	1
Phosphorus (mg/kg)	58	2	<1
Potassium (mg/kg)	120	66	98
Sulphur (mg/kg)	18	13	86
Calcium (mg/kg)	1700	270	250
Magnesium (mg/kg)	150	51	350
Micro elements			
Boron (mg/kg)	0.7	0.7	0.8
Copper (mg/kg)	3.5	0.1	0.1
Iron (mg/kg)	83	35	28
Manganese (mg/kg)	6	10	<1
Molybdenum (mg/kg)	0.01	0.01	0.01
Zinc (mg/kg)	1.5	<0.1	<0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	8.5	1.35	1.25
Magnesium (cmol(+)/kg)	1.2	0.4	2.9
Potassium (cmol(+)/kg)	0.3	0.2	0.3
Sodium (cmol(+)/kg)	0.2	0.0	0.2
Cation exchange capacity			
CEC (cmol(+)/kg)	10.2	2.0	4.6

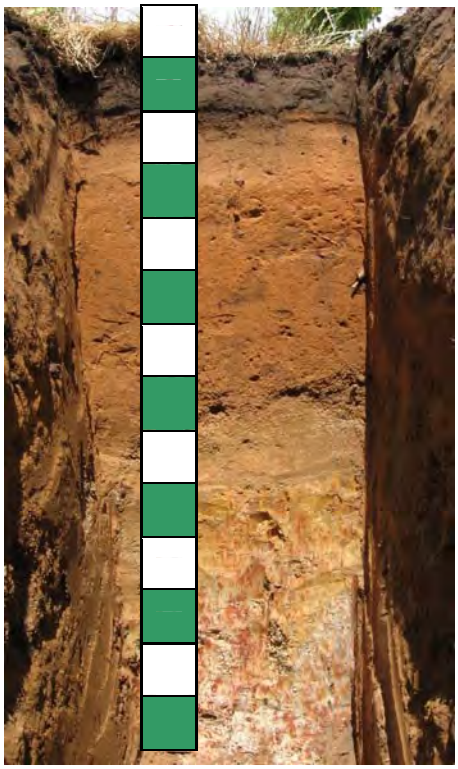
Soil type regional map

See Appendix A for a location map of these soils.

Soil Type 17: Keenan Loam

Profile

Soil group of Western Australia (Schoknecht 2002): Friable red-brown loamy earth/Brown loamy earth - red brown loam, with a dark brown organic surface, grading into a pedal clay loam to light clay. Often contains quartz material.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	15	0	15	Dark brown sandy loam
A2	65	15	80	Red brown loam with 10% quartz grit and pebbles
A3	20	80	100	Light yellow brown layer of loam with quartz grit and pebbles
B1	30	100	130	Light yellow clay with moderate red mottle
B2/C	15	130	145	White clay with heavy red mottle



Drainage

Moderately well to imperfectly drained, depending on the depth to clay. The poorly structured white clay subsoil generally has low permeability.

Potential root zone 130 cm in sampling pit.

Barriers to root growth

Abrupt textural changes such as the high percentage of quartz grit at 80cm, can be antagonistic to root exploration.

Water holding capacity
Readily available water 115mm

Fertility
Moderate natural fertility due to loam and clay texture. Slightly acidic.

Erosion potential
Moderate water erosion risk on slopes when soil is bare and unprotected. High wind erosion risk due to light surface soil.

Soil pit analysis

Horizon	A1	A2	A3	B1	B2/C
EC (1:5) (mS/m)	5	2	2	8	12
pH (CaCl2)	5.9	5.5	5.3	5.3	4
Organic Carbon (W/B) %	2.42	0.62	0.25	0.31	0.13
Macro elements					
Nitrate $N0_3$ (mg/kg)	3	1	1	1	1
Phosphorus (mg/kg)	>250	6	3	<1	<1
Potassium (mg/kg)	51	15	7	55	45
Sulphur (mg/kg)	10	7	6	83	170
Calcium (mg/kg)	1500	230	100	370	140
Magnesium (mg/kg)	99	23	25	310	190
Micro elements					
Boron (mg/kg)	0.5	0.4	0.2	0.6	0.5
Copper (mg/kg)	5.8	0.1	0.1	0.1	0.1
Iron (mg/kg)	150	52	160	60	57
Manganese (mg/kg)	23	7	2	<1	<1
Molybdenum (mg/kg)	0.02	0.01	0.01	<0.01	<0.01
Zinc (mg/kg)	6.3	<0.1	0.1	0.1	0.1
Exchangeable cations					
Calcium (cmol(+)/kg)	7.5	1.15	0.5	1.85	0.7
Magnesium (cmol(+)/kg)	0.8	0.2	0.2	2.5	1.6
Potassium (cmol(+)/kg)	0.1	0.0	0.0	0.1	0.1
Sodium (cmol(+)/kg)	0.1	0.0	0.0	0.2	0.3
Cation exchange capacity					
CEC (cmol(+)/kg)	8.5	1.4	0.7	4.7	2.7

Soil type regional map
See Appendix A for a location map of these soils.

MANAGEMENT ISSUES – KEENAN SOILS

Vine Performance: Vines grown on Keenan soils have moderate to high vigour due to soil depth and relatively high water holding capacity. Like Forrest Grove soils these soils allow well-balanced vine growth and are considered as highly suitable vineyard soils. They achieve good heat retention due to a high gravel content. Root growth and volume can be impeded when large amounts of granite rock and stones are present in the profile. These soils can be quite variable which may result in a lack of vine uniformity across blocks.

Irrigation practices: These soils have good water holding capacity. The profile rarely completely dries out due to the friable clay subsoil which supplies deficit available water. A range of different irrigation practices are successful on these soil types. Dryland production is viable on deeper loamy types with a friable clay subsoil due to the accessibility of water reserves in the subsoil.

Nutrition and soil amendments: These soils have a reasonably good inherent fertility. Lime is generally required to address acidity. Organic matter levels are generally adequate. Phosphorous requirement in establishment is high due to the high phosphorus fixing of these soils and a maintenance program is required to maintain available levels.

Vineyard floor management: These soils are reasonably trafficable and cover crops are easy to establish except where there is a very high stone content (e.g. Keenan Stony Duplex).

Soil Type 18: Yellow Sand

Profile

Soil group of Western Australia (Schoknecht 2002): Yellow deep sand/Yellow sandy earth - a yellowish siliceous sand to clayey sand with a brownish organic stained topsoil, often grading into a sandy loam or sandy clay loam, at depths of about 1-2 metres.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	20	0	20	Pale grey brown loamy sand with bleached surface
A2	150	20	170	Yellow sand
B	35	170	205	Light yellow brown sandy clay



Drainage

Very well drained.

Potential root zone 205 cm in sampling pit.

Barriers to root growth

None.

Water holding capacity
Readily available water 88mm

Fertility
Moderately low fertility. Often slightly acidic. The colour indicates that this soil is not as highly leached as other sandy soils in the region.

Erosion potential
Can be highly erodable on slopes. Topsoil is subject to wind erosion.

Soil pit analysis

Horizon	A1	A2	B
EC (1:5) (mS/m)	5	1	3
pH (CaCl2)	5.6	5.4	5.6
Organic Carbon (W/B) %	1.29	0.17	0.12
Macro elements			
Nitrate $N0_3$ (mg/kg)	5	1	1
Phosphorus (mg/kg)	150	2	3
Potassium (mg/kg)	42	4	3
Sulphur (mg/kg)	10	10	15
Calcium (mg/kg)	630	50	65
Magnesium (mg/kg)	59	8	14
Micro elements			
Boron (mg/kg)	<0.1	<0.1	<0.1
Copper (mg/kg)	12	0.2	0.2
Iron (mg/kg)	130	31	12
Manganese (mg/kg)	8	<1	<1
Molybdenum (mg/kg)	0.01	0.03	<0.01
Zinc (mg/kg)	3.6	<0.1	0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	3.15	0.25	0.33
Magnesium (cmol(+)/kg)	0.5	0.1	0.1
Potassium (cmol(+)/kg)	0.1	0.0	0.0
Sodium (cmol(+)/kg)	0.0	0.0	0.0
Cation exchange capacity			
CEC (cmol(+)/kg)	3.8	0.3	0.5

Soil type regional map
See Appendix A for a location map of these soils.

Other Yellow Sands

There are five other soil types classified as Yellow Sands which were not described and analysed as soil profiles matching their descriptions were not found during the survey process.

Soil Type 19

Soil group of Western Australia (Schoknecht 2002): Alluvial Yellow Sand - Brown sandy/loamy earths - a dark organic stained sand grading into a yellow sand to sandy loam which grades into a yellowish sandy clay loam at 1.5 metres.

Soil Type 20

Soil group of Western Australia (Schoknecht 2002): Leached Yellow Sand - Pale deep sand - a pale siliceous sand, with a grey organic stained surface, overlying a yellow siliceous sand subsoil at about 50 cm.

Soil Type 21

Soil group of Western Australia (Schoknecht 2002): Deep Brownish/Yellow Spearwood Sand -Yellow deep sand/Brown deep sand to a brownish - yellow sand, overlying limestone at a depth of greater than one metre, with a brown organic stained topsoil.

Soil Type 22

Soil group of Western Australia (Schoknecht 2002): Shallow Brownish/Yellow Spearwood Sand – Yellow-brown shallow sand to a brownish - yellow sand, overlying limestone at a depth of 50 cm or less, with a brown organic stained topsoil.

MANAGEMENT ISSUES – YELLOW SANDS

Vine Performance: These soils promote moderate to vigorous growth due to optimal root growth conditions. The topsoil warms quickly in spring allowing good spring growth. Careful water and nutrition management is required to achieve moderately to high yields. Block variation has been observed due to variation in the depth to clay.

Irrigation practices: Close emitter spacing is required to achieve a continual wet under vine strip. Frequent irrigations of short duration may be required to maintain adequate soil moisture tension in the upper 60cm. Due to the depth of sand good water management is required on these soils when establishing vines. Once roots have penetrated the clay subsoil, vine growth is generally easier to manage.

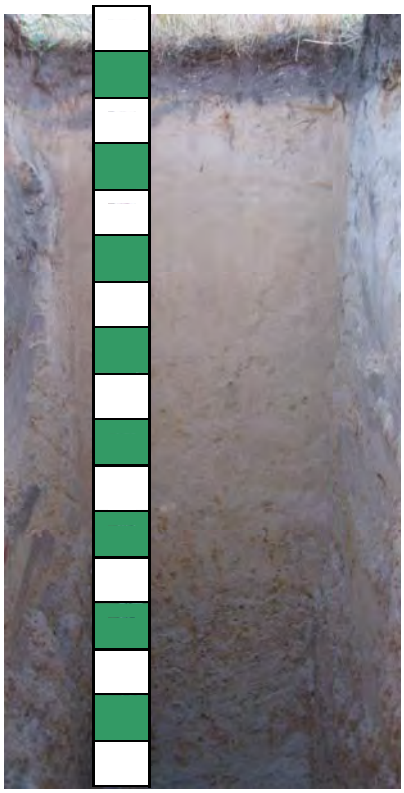
Nutrition and soil amendments: Good nutrient management is required due to the limited nutrient holding capacity of these soils. Low pH levels are common and therefore lime is usually required. These soil types benefit from mulching and other practices to increase the organic matter content.

Vineyard floor management: These soils benefit from the establishment and growth of cover crops. Many cover crops, such as oats and ryegrass are unlikely to persist until the end of the season due to the low water holding capacity of the soil.

Soil Type 23: Deep Busselton Sand

Profile

Soil group of Western Australia (Schoknecht 2002): Semi-wet soil/Pale deep sand/Pale sandy earth - grey sand overlying a brownish sand or sandy loam which grades into a yellowish/greyish/brownish sandy clay loam or sandy clay at about a metre.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	15	0	15	Grey loamy sand
A2	100	15	115	Light grey brown sandy loam
B	50	115	165	Light grey brown sandy clay with ironstone 10% gravel



Drainage

Moderately to imperfectly drained depending on location. Generally poorly drained when located in low lying areas and moderately well drained with elevation. Vineyards in low lying areas often require subsurface drainage.

Potential root zone 130 cm in sampling pit.

Barriers to root growth

Waterlogging and soil compaction.

Water holding capacity
Readily available water 98mm

Fertility
Low. Naturally acidic surface soil.

Erosion potential
High risk of wind erosion. Low water erosion risk in low lying areas.

Soil pit analysis

Horizon	A1	A2	B
EC (1:5) (mS/m)	6	1	3
pH (CaCl2)	5.6	4.6	6
Organic Carbon (W/B) %	2.82	0.15	0.11
Macro elements			
Nitrate $N0_3$ (mg/kg)	3	<1	2
Phosphorus (mg/kg)	81	4	<1
Potassium (mg/kg)	35	1	5
Sulphur (mg/kg)	14	6	63
Calcium (mg/kg)	1100	24	230
Magnesium (mg/kg)	64	3	77
Micro elements			
Boron (mg/kg)	<0.1	<0.1	0.1
Copper (mg/kg)	0.7	<0.1	<0.1
Iron (mg/kg)	140	34	35
Manganese (mg/kg)	4	1	<1
Molybdenum (mg/kg)	<0.01	0.01	<0.01
Zinc (mg/kg)	0.5	0.1	<0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	5.5	0.12	1.15
Magnesium (cmol(+)/kg)	0.5	0.0	0.6
Potassium (cmol(+)/kg)	0.1	0.0	0.0
Sodium (cmol(+)/kg)	0.1	0.0	0.0
Cation exchange capacity			
CEC (cmol(+)/kg)	6.2	0.2	1.8

Soil type regional map
See Appendix A for a location map of these soils.

Other Busselton Sands

There are two other soil types classified as Busselton Sands which were unable to be thoroughly described in the profile as soil profiles matching their descriptions were not found during the survey process.

Soil Type 24

Soil group of Western Australia (Schoknecht 2002): The Busselton Sand Semi-wet soil/Pale sandy earth - approximately 15 cm of a grey sand overlying a brownish sand or sandy loam which grades into a yellowish/ greyish/brownish sandy clay loam or sandy clay at about 50 cm.

Soil Type 25

Soil group of Western Australia (Schoknecht 2002): Bleached Busselton Sand Semi-wet soil/Pale sandy earth - approximately 30 cm of pale greyish sand, with grey organic stained surface, overlying a brownish sand or sandy loam which grades into a yellowish/greyish/brownish sandy clay loam or sandy clay at about a metre.

MANAGEMENT ISSUES – BUSSELTON SANDS

Vine Performance: These soil types are typically found in the low lying areas of the Abba Wet Flats, with smaller areas planted on the low rises of the Abba Flats. As such, vine performance will depend on geographic location. Those found on the wet flats generally require subsurface drainage to improve rooting depth. Variation in vine vigour is common due to variation in depth to clay and presence of a high water. These soils are more suited to white varieties. Soil compaction from machinery is common and results in limited root exploration. Where these soils are found in low laying areas they are generally not suitable for viticulture as they that are difficult to drain. These soils can be used where they are found on rises and where drainage is better.

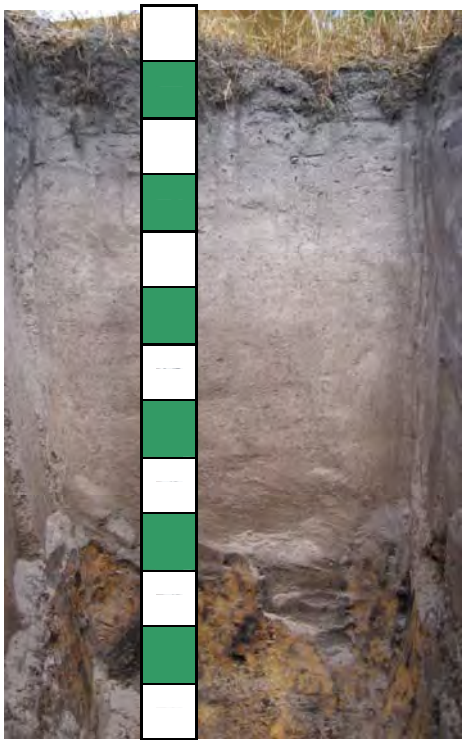
Irrigation practices: Whilst the topsoils have poor water holding capacity, moisture is often retained in the clayey subsoils at depth. Vines grown on these soils often have permanent access to the water table. The reduced lateral spread of water from drippers requires a close emitter spacing. Vines on these soils generally need to be irrigated little and often. These soils are non wetting and can be difficult to re-wet once they have been allowed to dry out.

Nutrition and soil amendments: They are generally low in organic matter with a low inherent fertility, CEC and buffering capacity. They often require a large degree of inputs and general soil conditioning.

Vineyard floor management: The establishment of a cover crop is often difficult to establish and additional nutrition is usually required in spring to maximize biomass. Soil compaction from machinery is a common problem that is difficult to remedy due to the texture of the soil.

Soil Type 26: Bleached Sand

Profile
Soil group of Western Australia (Schoknecht 2002): Pale deep sand - a pale grey to white siliceous sand, approximately 1 m deep, with a grey organic stained topsoil.



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	20	0	20	Organic stained grey sand with bleached surface
A2	85	20	105	Pale grey sand
B	30	105	135	Cemented yellow clayey sand with decaying organic matter



Drainage
A well drained soil, though there can be drainage barriers at depth.

Potential root zone 105 cm in sampling pit.

Barriers to root growth
Cemented clayey sand at depth and soil compaction.

Water holding capacity
Readily available water 33mm

Fertility

Very low inherent fertility. This soil is highly leached and has little nutrient retention capacity. Colloquially referred to throughout the region as “gutless sand”.

Erosion potential

High wind erosion risk. Water erosion is a risk on slopes.

Soil pit analysis

Horizon	A1	A2	B
EC (1:5) (mS/m)	15	4	1
pH (CaCl2)	5	4.6	5.2
Organic Carbon (W/B) %	2.7	0.42	0.13
Macro elements			
Nitrate $N0_3$ (mg/kg)	28	3	1
Phosphorus (mg/kg)	73	5	1
Potassium (mg/kg)	67	10	4
Sulphur (mg/kg)	22	18	6
Calcium (mg/kg)	890	36	39
Magnesium (mg/kg)	96	12	13
Micro elements			
Boron (mg/kg)	<0.1	<0.1	0.3
Copper (mg/kg)	1.6	0.2	0.1
Iron (mg/kg)	44	53	37
Manganese (mg/kg)	15	<1	<1
Molybdenum (mg/kg)	<0.01	<0.01	0.02
Zinc (mg/kg)	3.8	0.2	<0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	4.45	0.18	0.195
Magnesium (cmol(+)/kg)	0.8	0.1	0.1
Potassium (cmol(+)/kg)	0.2	0.0	0.0
Sodium (cmol(+)/kg)	0.2	0.0	0.0
Cation exchange capacity			
CEC (cmol(+)/kg)	5.6	0.3	0.3

Soil type regional map

See Appendix A for a location map of these soils.

MANAGEMENT ISSUES – BLEACHED SAND

Vine Performance: Bleached sands are generally not classed as suitable for viticulture due to their sandy texture and associated low water holding capacity and low inherent fertility. Sauvignon blanc and Shiraz are two varieties that can be grown successfully on these soils with good management. These soils are often planted where they occur in small pockets within areas of better soil.

Irrigation practices: These soils have a low water holding capacity and need to be irrigated frequently in order to maintain vine growth and health. Emitters need to be spaced closely to provide uniform soil moisture. The soil profile can be very deep with poor stucture and are not conducive to root exploration. They can be difficult to re-wet if allowed to dry out.

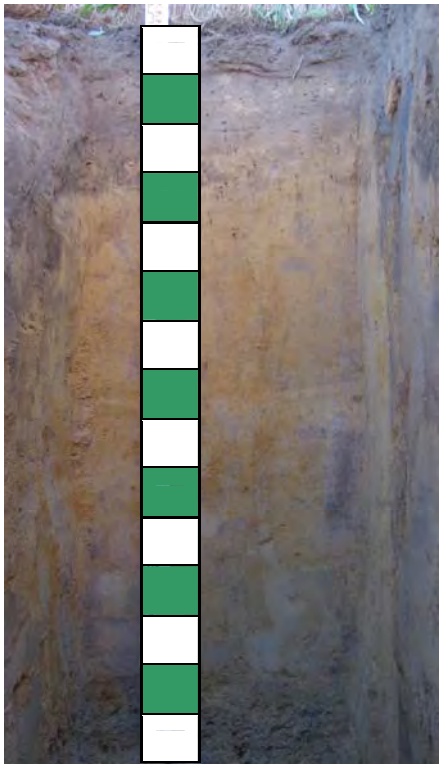
Nutrition and soil amendments: Low inherent fertility and a sandy texture requires frequent additions of nutrients to maintain vine growth. Organic matter inputs are required.

Vineyard floor management: A good cover crop sward is difficult to establish due to the infertile, bleached topsoil.

Soil Type 27: Abba Sand/Deep Abba Sand

Profile

Soil group of Western Australia (Schoknecht 2002): Pale deep sand/Semi wet soil - a light grey sand, with a grey organic stained surface, overlying an apedal yellowish/greyish/brownish sandy clay loam or sandy clay at 50cm (Abba Sand) or 1 metre (Deep Abba sand).



Horizon	thickness (cm)	upper depth (cm)	lower depth (cm)	Description
A1	30	0	30	Pale brownish grey sand
A2	95	30	125	Yellow brown sand
B	25	125	150	Yellowish sandy clay



Drainage

Imperfectly drained. Generally considered a “wet” or “semi-wet” soil.

Potential root zone 150 cm in sampling pit.

Barriers to root growth

Root growth can be restricted by anaerobic conditions induced by waterlogging.

Water holding capacity
Readily available water 55.1mm

Fertility
Low fertility due to the sandy texture and bleached A2 horizon. Often acidic with a low cation exchange capacity.

Erosion potential
High wind erosion risk. Water erosion is a risk on slopes.

Horizon	A1	A2	B
EC (1:5) (mS/m)	3	2	3
pH (CaCl2)	4.3	4.4	4.3
Organic Carbon (W/B) %	3.26	0.3	0.14
Macro elements			
Nitrate $N0_3$ (mg/kg)	4	1	1
Phosphorus (mg/kg)	46	3	1
Potassium (mg/kg)	25	14	1
Sulphur (mg/kg)	27	38	95
Calcium (mg/kg)	250	31	25
Magnesium (mg/kg)	18	5	5
Micro elements			
Boron (mg/kg)	0.1	<0.1	<0.1
Copper (mg/kg)	0.9	<0.1	<0.1
Iron (mg/kg)	200	46	38
Manganese (mg/kg)	5	10	<1
Molybdenum (mg/kg)	0.01	<0.01	<0.01
Zinc (mg/kg)	0.5	<0.1	<0.1
Exchangeable cations			
Calcium (cmol(+)/kg)	1.25	0.155	0.125
Magnesium (cmol(+)/kg)	0.1	0.0	0.0
Potassium (cmol(+)/kg)	0.1	0.0	0.0
Sodium (cmol(+)/kg)	0.0	0.0	0.0
Cation exchange capacity			
CEC (cmol(+)/kg)	1.5	0.2	0.2

Soil type regional map
See Appendix A for a location map of these soils.

MANAGEMENT ISSUES – ABBA SAND

Vine Performance: These soils are generally not suitable for viticulture since they are often wet, cold, and located in low lying areas that are prone to waterlogging. They often require subsurface drainage in order for vines to grow productively. Soil compaction occurs with traffic when the soil is wet, compressing the root zone.

Irrigation practices: There is little control over water status early in the season (wet) and later in the season the soil is prone to drying out. Close emitter spacing is required to achieve adequate water under vine. Subsurface drainage is generally a requirement.

Nutrition and soil amendments: These soils generally require high nutrition and organic matter inputs.

Vineyard floor management: The light textured topsoil benefits from high biomass cover crop species, which can also be used to reduce excess water in spring.

These soils were unable to be identified during the soil survey process for this profile.

Soil Type 28: Wet Sand

Soil group of Western Australia (Schoknecht 2002): Wet soil/Semi wet soil - a winter wet siliceous sand, over 1 metre deep with dark organic topsoil, and a subsoil which is sometimes bleached.

Soil Type 29: Gravelly Sand

Soil group of Western Australia (Schoknecht 2002): A pale, siliceous sand with a grey, organic stained topsoil overlying either laterite or a gravelly sand at a depth of 50 cm or less.

Soil Type 30: Gritty Sand/Gritty Duplex

Soil group of Western Australia (Schoknecht 2002): Gritty sand - pale deep sand - a coarse pale to white sand or quartz grit one metre or more deep.
Gritty duplex - brown deep loamy duplex/Yellow-brown deep sandy duplex - coarse, gritty sandy topsoil with a clear boundary to gritty clay subsoil.

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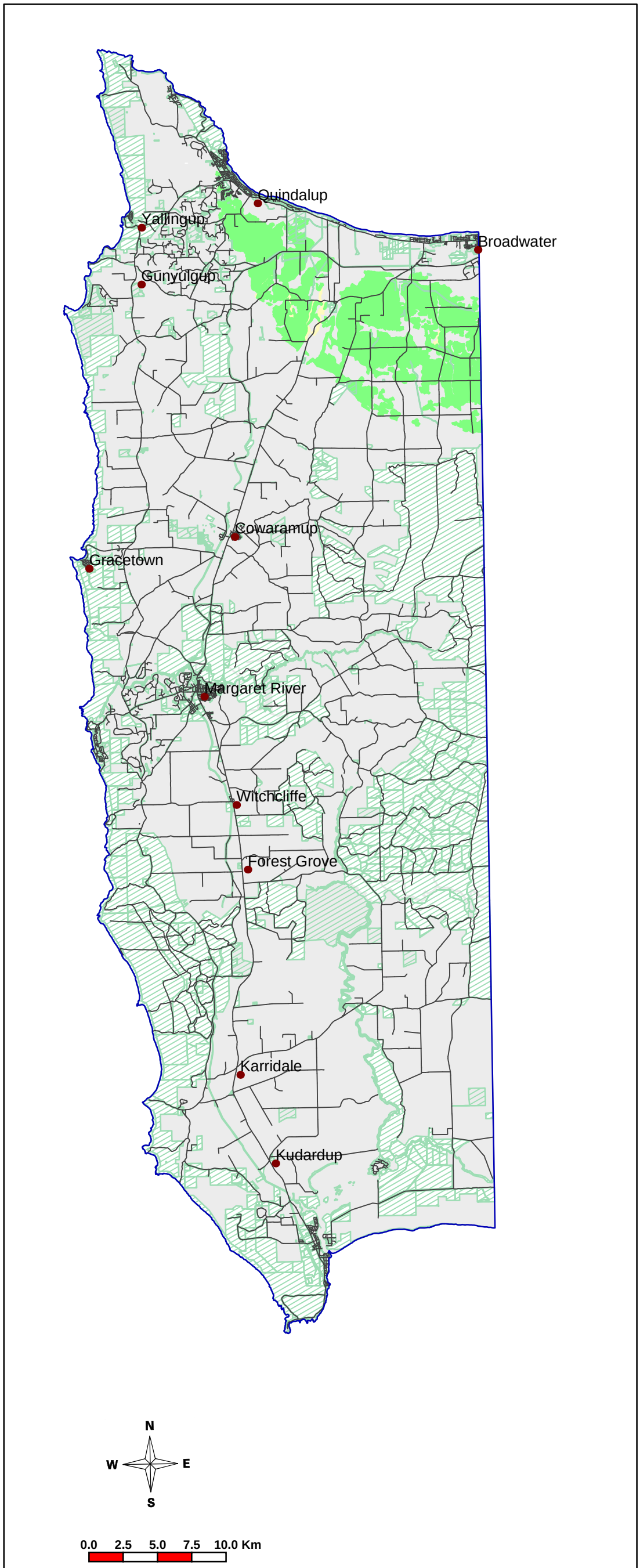
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MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY



Abba soils

Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
- Major soil type occupies between 25 and 50% of map unit
- Common soil type occupies between 10 and 25% of map unit
- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

Soil map unit database DAFWA

Data analysis by P Tille DAFWA Bunbury Office

Map prepared by K Kuswardiyanto DAFWA Bunbury Office

Reference no. : BY2006027

Date : November 2006

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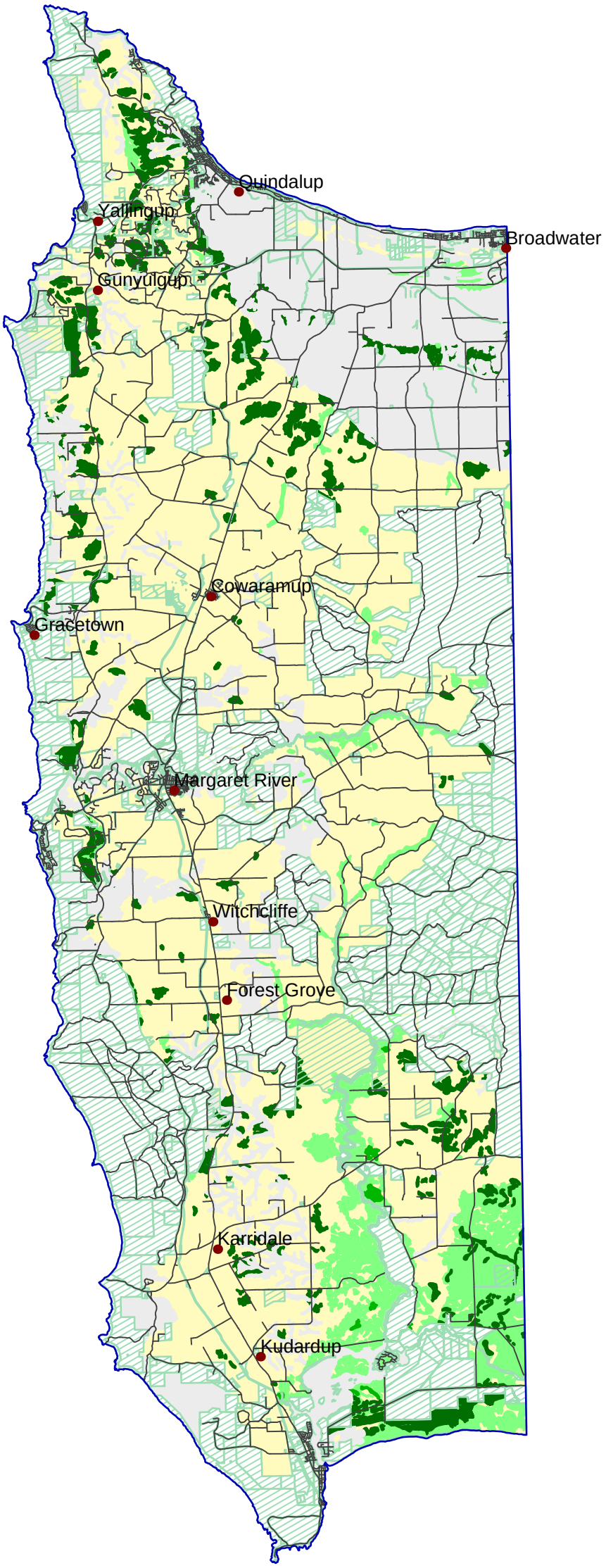
Department of Agriculture and Food
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MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY

Bleached sand soils



Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
- Major soil type occupies between 25 and 50% of map unit
- Common soil type occupies between 10 and 25% of map unit
- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

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GDA

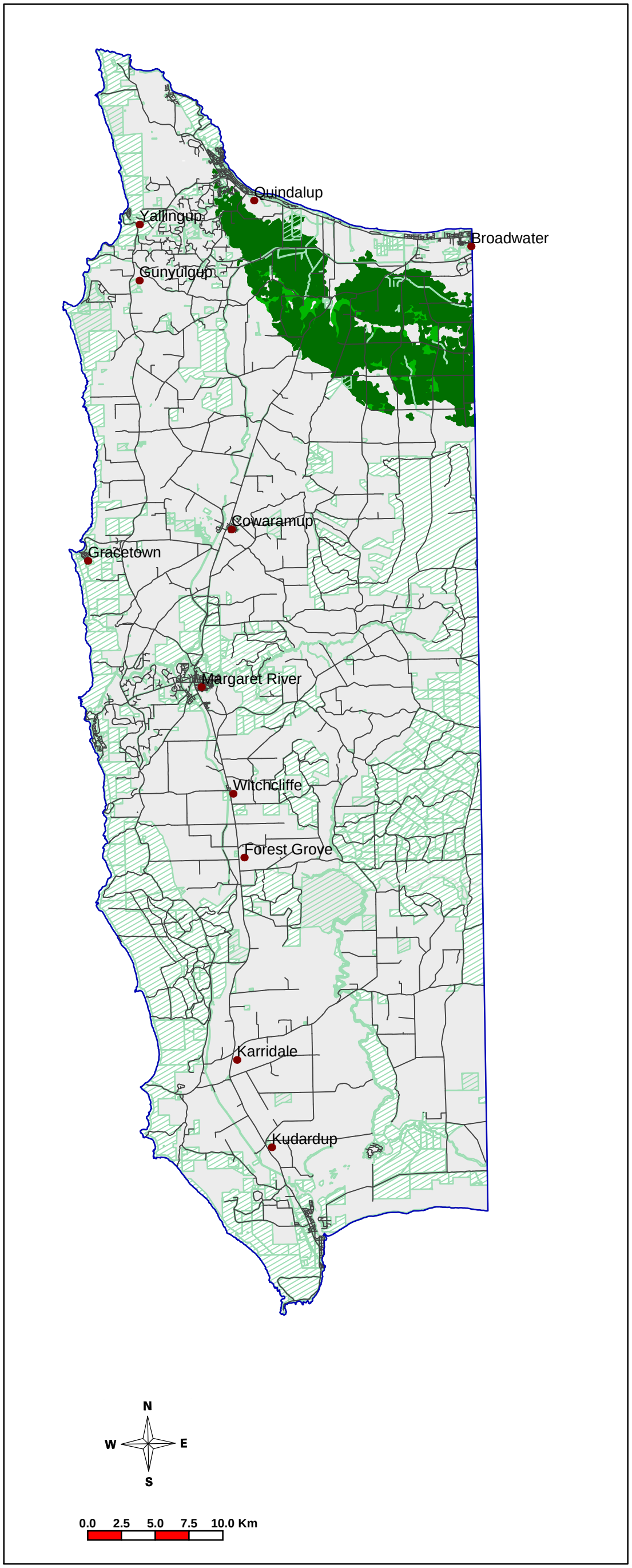
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MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY

Busselton sand soils



Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
- Major soil type occupies between 25 and 50% of map unit
- Common soil type occupies between 10 and 25% of map unit
- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

Soil map unit database DAFWA

Data analysis by P Tille DAFWA Bunbury Office

Map prepared by K Kuswardiyanto DAFWA Bunbury Office

Reference no. : BY2006027

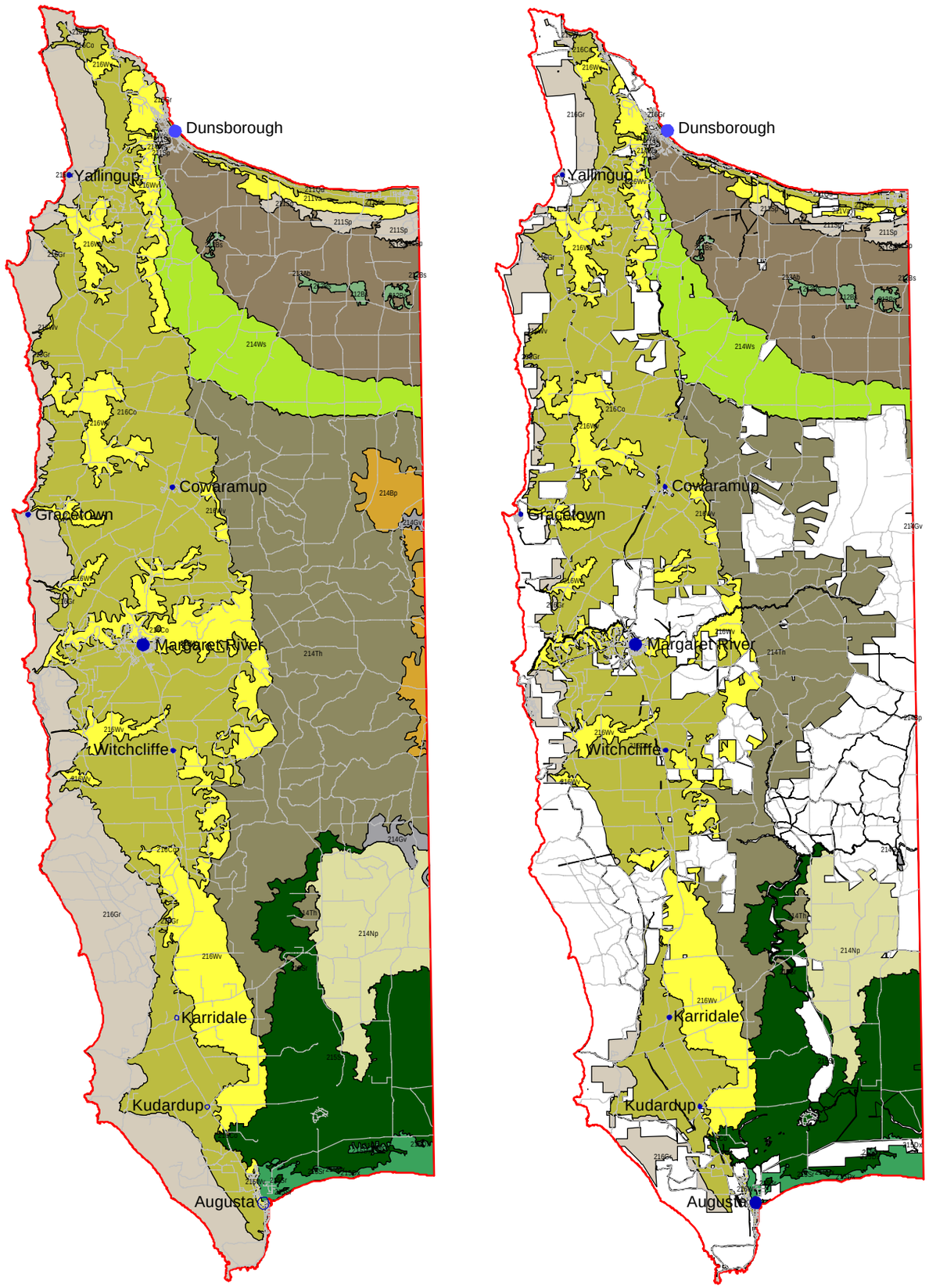
Date : November 2006

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DRAFT

Soil Landscape Systems in the Cape to Cape region





Legend

- Roads
- Soil Systems
- 211Qu (Quindalup South System) - 1,267Ha - private 1,001Ha
- 211Sp (Spearwood System) - 1,482Ha - private 1,408Ha
- 211Va (Vasse System) - 1,349Ha - private 1,101Ha
- 212Bs (Bassendean System) - 667Ha - private 667Ha
- 213Ab (Abba System) - 16,847Ha - private 16,705Ha
- 214Bp (Blackwood Plateau System) - 3,555Ha - private 18Ha
- 214Gv (Goodwood Valleys System) - 1,016Ha - private 93Ha
- 214Np (Nillup Plain System) - 9,381Ha - private 7,186Ha
- 214Th (Treeton Hills System) - 44,987Ha - private 25,951Ha
- 214Ws (Whicher Scarp System) - 10,092Ha - private 9,616Ha
- 215Dx (D'Entrecasteaux Dunes System) - 1,975Ha - private 1,458Ha
- 215Sr (Scott River Plain System) - 18,022Ha - private 13,747Ha
- 216Co (Cowaramup Uplands System) - 51,427Ha - private 43,366Ha
- 216Gr (Gracetown Ridge System) - 27,146Ha - private 7,187Ha
- 216Wv (Wilyabrup Valleys System) - 24,347Ha - private 19,315Ha

Map produced by: B.E.Stephenson, Department of Agriculture, Bunbury
Map requested by: L.Clearwater, Haak & Associates, Dunsborough
Date: 05/08/2005
File: BY2005043

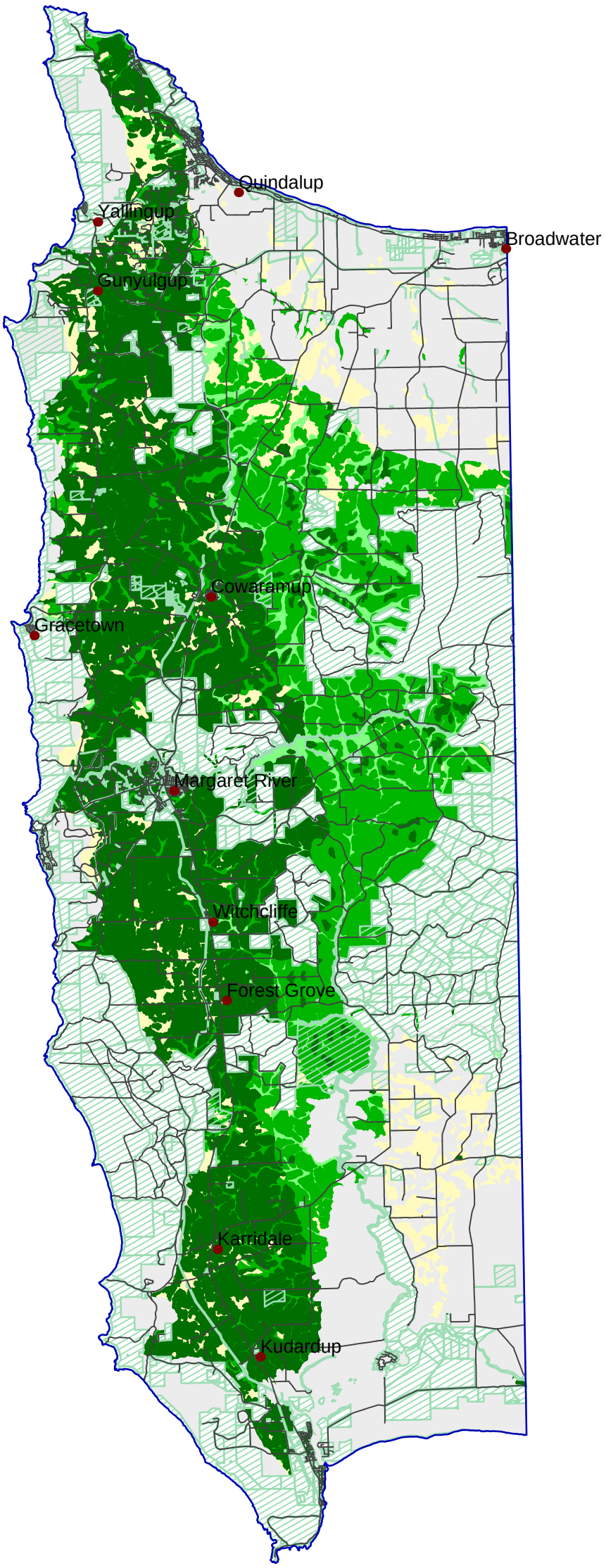
Department of Agriculture
Government of Western Australia

MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY

Forest Grove soils



Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
- Major soil type occupies between 25 and 50% of map unit
- Common soil type occupies between 10 and 25% of map unit
- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

Soil map unit database DAFWA

Data analysis by P Tille DAFWA Bunbury Office

Map prepared by K Kuswardiyanto DAFWA Bunbury Office

Reference no. : BY2006027

Date : November 2006

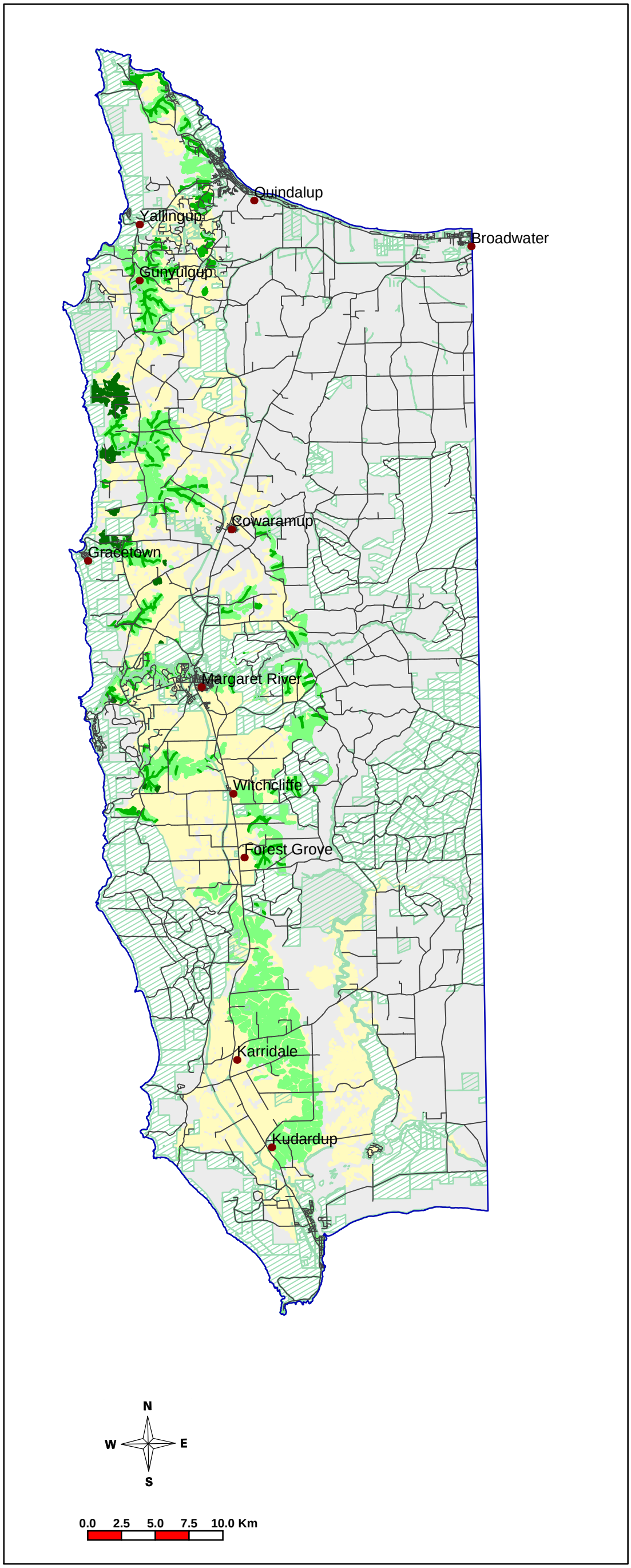
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Government of Western Australia

MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY



Keenan soils

Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
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- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

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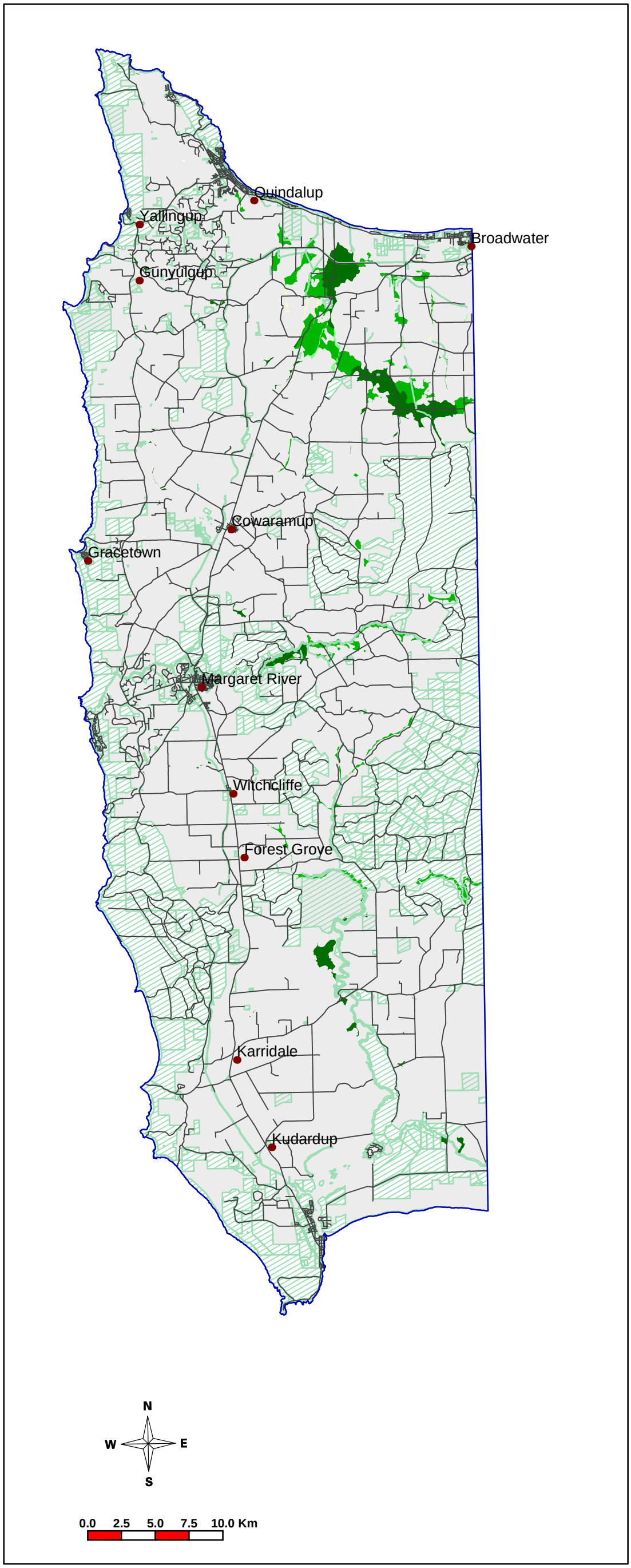
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Government of Western Australia

MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY



Marybrook soils

Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
- Major soil type occupies between 25 and 50% of map unit
- Common soil type occupies between 10 and 25% of map unit
- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

Soil map unit database DAFWA

Data analysis by P Tille DAFWA Bunbury Office

Map prepared by K Kuswardiyanto DAFWA Bunbury Office

Reference no. : BY2006027

Date : November 2006

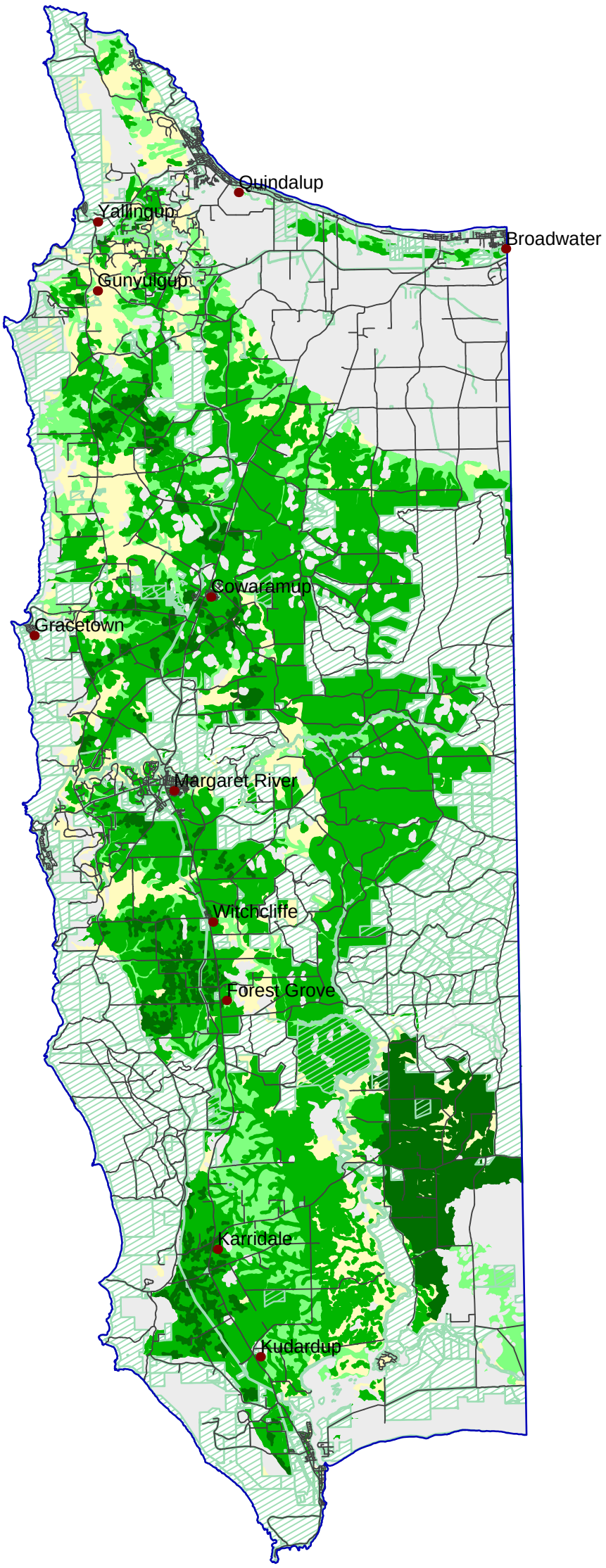
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Department of Agriculture and Food
Government of Western Australia

MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY



Mungite soils

Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
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- Common soil type occupies between 10 and 25% of map unit
- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

Soil map unit database DAFWA

Data analysis by P Tille DAFWA Bunbury Office

Map prepared by K Kuswardiyanto DAFWA Bunbury Office

Reference no. : BY2006027

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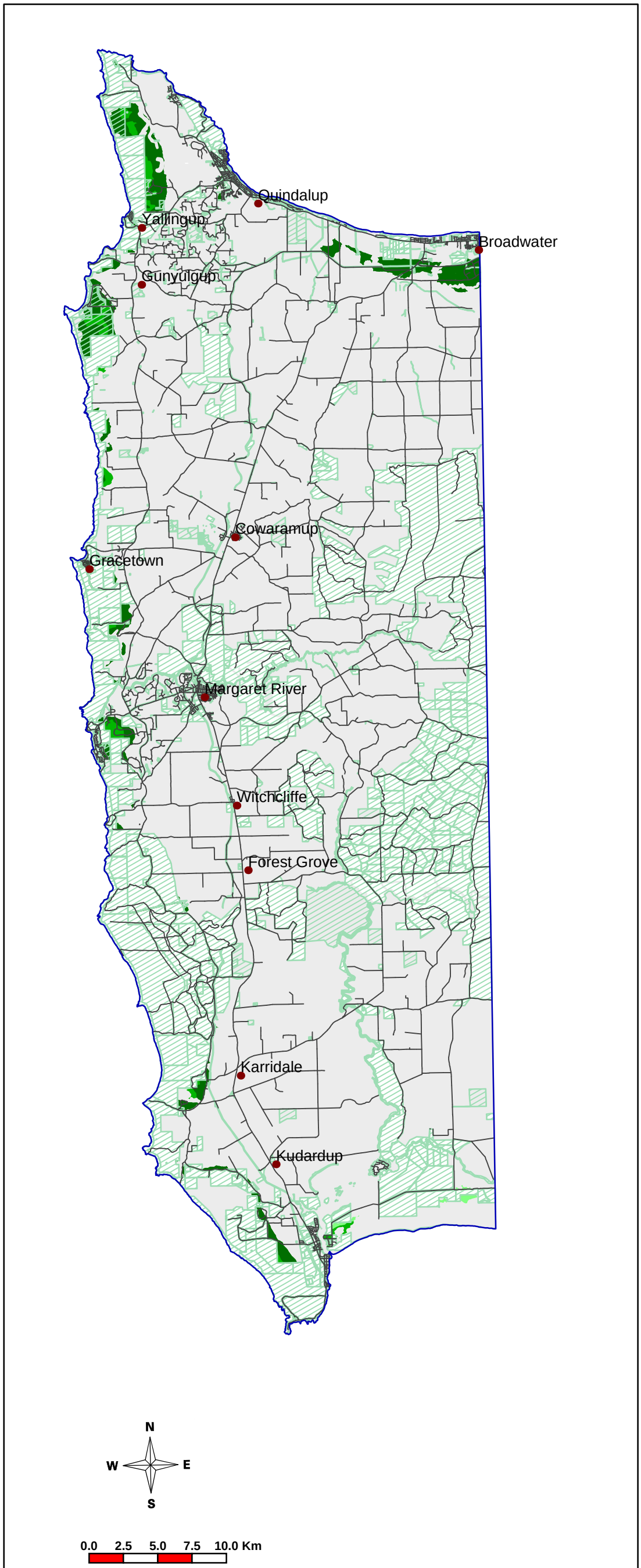
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Government of Western Australia

MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY



Spearwood sand soils

Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
- Major soil type occupies between 25 and 50% of map unit
- Common soil type occupies between 10 and 25% of map unit
- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

Soil map unit database DAFWA

Data analysis by P Tille DAFWA Bunbury Office

Map prepared by K Kuswardiyanto DAFWA Bunbury Office

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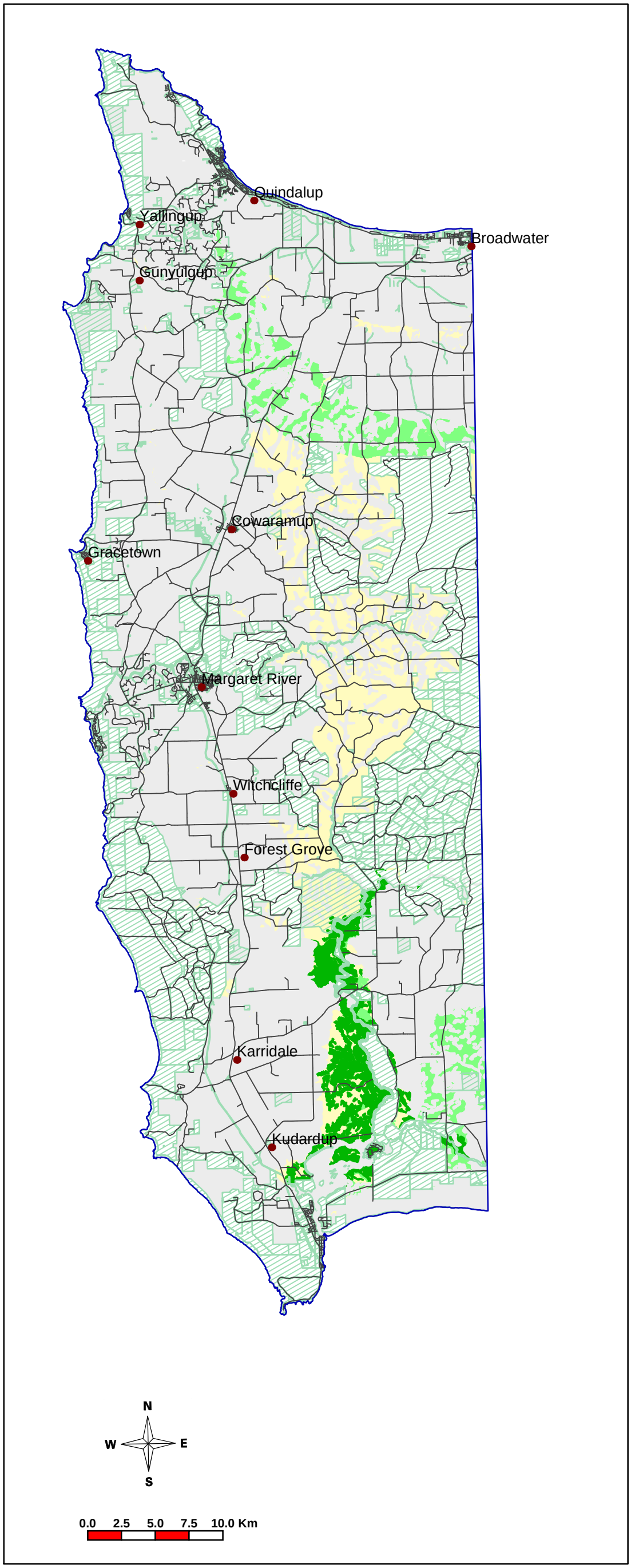
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Government of Western Australia

MARGARET RIVER REGION

SOIL TYPE DISTRIBUTION

ON PRIVATE PROPERTY



Yellow sand soils

Legend

- Margaret River Region boundary
- Roads
- Towns
- Dominant soil type occupies more than 50% of Map unit
- Major soil type occupies between 25 and 50% of map unit
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- Minor soil type occupies < 10% of map unit
- Soil type not present
- Non agriculture area

Projection : Universal Transverse Mercator, Zone 50

Datum : Geocentric datum of Australia 1994

Data source :

CRIS property database DAFWA

Soil map unit database DAFWA

Data analysis by P Tille DAFWA Bunbury Office

Map prepared by K Kuswardiyanto DAFWA Bunbury Office

Reference no. : BY2006027

Date : November 2006

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