PRODUCTIVE SALTLAND PASTURES

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Salinity Manual

Module 5

Geology, drainage zones, groundwater discharge + baseflow

GILLAMII CENTRE

GOVERNMENT OF WESTERN AUSTRALIA

Department of Primary Industries and Regional Development

natural resource management program

All photos from SGSL DAFWA team

INTRODUCTION

To gain an understanding of groundwater movement in the landscape, a brief explanation of the geology and its relationship to drainage is required.

GEOLOGY

The geology of the South West is dominated by the Yilgarn Craton, an ancient and relatively stable area of granites and gneiss (a metamorphic banded granite-like rock). The western boundary is the Darling Fault which is one of the largest lineaments in the world at 1000km long with a topographical expression up to 200m in height. (Tille et al, 2001). As a major structural component of the groundwater system, it influences salinity through its impact on groundwater movement and water quality.

The Yilgarn Craton contains numerous faults, shear zones and dolerite dykes which affect groundwater movement in various ways. The crystalline rocks have a low permeability and, in most cases, form a barrier to groundwater movement. The lower regolith weathered from the parent rock have different hydrological properties and are often able to carry water at higher permeability than the fresh crystalline rock. At the base of the regolith is often a layer of poorly weathered minerals (gritty sands often referred to as saprolite) which has a higher permeability.

Monitoring salinity levels, using an EM 38 instrument, of the upper 50cm of soil profile in a saline creek system in Darkan, WA. Salinity in this area is strongly influenced by the underlying geological features.

DRAINAGE ZONES

The region can be divided into three distinct drainage zones based on faults and resulting uplifts.

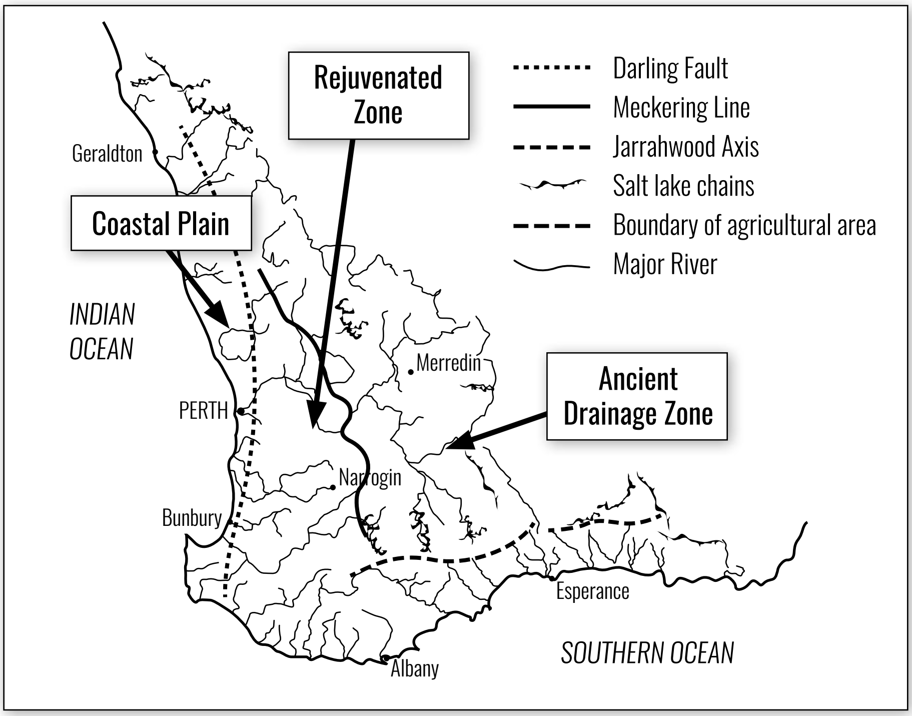


Figure 1: Main geological Faults and Axis relative to drainage lines and lakes.

THE COASTAL PLAIN

The Coastal Plain, also known as the Perth Basin, lies on the west coast of the SW agricultural region and to the east of the Darling Fault (dotted line on Fig 1). The Darling Range is associated with the Darling Fault and provides a useful visual of the boundary between the Fault and the Rejuvenated Zone. It consists of sediments derived from outwash from the wheatbelt to marine sediments from incoming seas. The sediments are highly permeable. It has relatively few large waterways but contains large aquifers such as the Leederville and Yarragadee. It is dominated by deep sand and very deep regolith (>2km).

THE REJUVENATED ZONE

The Rejuvenated Zone is the region between the Darling Range Fault and the Meckering Line (Fig 1). The major rivers are Hotham, Williams, Beaufort, Balgorup, Gordon and Arthur Rivers. The landscape is more dissected, often with variable soils formed from dissected laterite profiles and underlying crystalline rock. Grey and brown gravelly soils and sheet ironstone are common as you get closer to the coast.

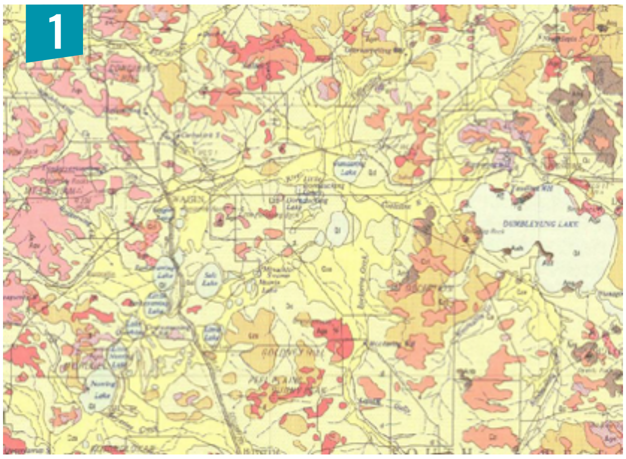
THE ANCIENT DRAINAGE ZONE

The Ancient Drainage Zone is where the landscape is more subdued and lies to the west of the Meckering Line and North of the Jarrahwood Axis (Fig 1). Soils and landscape are recognized with frequent yellow sandy gravel uplands and wide, flat drainage systems, with salt lakes (Fig 3). The boundary between this and the rejuvenated zone is the Meckering Line. In most years runoff from this zone does not reach the sea. Major surface storages are lakes such as Lake Dumbleyung, Parkeyerring, Norring, White and Normans which do not fill and overflow regularly.

There are marked differences in the underlying rocks, which weather and erode in distinctive ways. Differential weathering of rock types, faulting and geological uplift have had large effects on landscape relief and soil types (Fig 2). This variation means that parts of similar landscape can have hydrological behavior with little or no connection between them, hence the term 'Cells" where aquifers are connected within a cell, but the cells are not connected.

The geology of the Wagin and Dumbleyung district of the wheatbelt is shown in Map 1 and illustrate many of the features found such as lakes, major rock formations and waterways. Map 2 shows the faults and dolerite dykes in Katanning district.

The major rock bands of the Yilgarn Craton reflect its formation over many years as 'rafts' of land on tectonic plates collided with each other to form bands of gneiss that were intruded by granites. Stresses associated with these events caused cracking and intrusion of the dolerite dykes that occur throughout the craton.



Map 1: A map showing the geology of the Wagin-Dumbelyung district of the wheatbelt.

Map 2: A geological map of the Katanning District showing faults (solid black lines) and dolerite dykes (solid green and yellow lines). (Sawkins, D. 2008)

Parent material of wind and water born deposits, laterites and soils are granite, dolerite, quartz, which are all igneous rocks, and gneiss, migmatite and banded ironstone, which are metamorphic rocks. Outcrops or remnants are relatively common in the rejuvenated areas.

SOIL PROFILES

Soil type greatly influences water flow across the land surface and down to groundwater aquifers. Soil type also directly influences salt storage, salinity expression and salinity management. The dominant soil types of the South Coast are various lateritic soils, deep sands and duplex (sand over clay) soils.

LATERITE AND PODSOL SOIL

Laterites and podsols are soils with a leached, sandy topsoil ('A' horizon) overlying a horizon rich in iron and aluminum ('Sesqui-oxide' horizon). Laterites, and the less-well developed podsols, form in a similar way on well-drained, neutral to acidic profiles on the geological parent materials described above. Sesqui-oxide horizons of gravel and iron-pans form under native vegetation that form specialized roots called cluster (or proteiod) roots. This vegetation is widespread and very diverse in Western Australia, comprising principally of species from the Proteaceae family, which includes the well-known genuses of Banksia, Dryandra, Grevillea, and Hakea, amongst others. Some species of Allocasuarina (she-oak) and even some crop plants (eg Lupinus sp) also grow cluster roots. Cluster roots exude copious quantities of organic acids that bind to metal components of soil, including iron and aluminium (and other metals like magnesium, calcium, uranium, thorium and gallium). This bio-chemical process is called chelation. The organic-metal chelate isolates the metal ion from reacting with other soil components and is soluble, and therefore mobile, in water. Mobilizing these metals allows plants to access phosphorus, which is normally bound to insoluble iron and aluminium. Other chemicals exuded by cluster roots and soil microbes are then able to 'mop up' soil phosphorus and render it available to plants through soil water imbibed by roots (see photos of cluster roots and cluster roots surrounding gravels).

The chelated metals are free to move with percolating soil water, and the organic acid component of the chelate are rich food sources for soil biota. Soil water not drawn up by plants flows downwards through root channels and larger pores of the soil until it encounters fine pores on gravel and root channel surfaces, where capillary suction draws the cocktail in (see Figures 2a and 2b). These micro-pore regions of the soil maintain thin water films throughout wet and dry seasons and so can harbour colonies of soil microbes, which consume the organic portion of the chelate, and precipitate the metallic portion (see Figure 2b and 2c). In this way, the characteristic 'onion rinds' of gravels are formed, as are the dark iron-stains down margins of root channels and other areas where coarse soil-matrices meet finer-earth soil materials (see Figure 2).

Figure 2: Photographs of iron-rich features in laterite.

Figure 2a: Iron oxide precipitation on root channel margin

Iron oxides (goethite and haematite) concentrating on the internal margins of root channels. Precipitation is most intense right at the margin, presumably where bacteria are congregating to feed on organic acids flowing down the channels

Figure 2b: Iron oxide precipitation on ironstone gravel

Gravel split open to reveal concentric rinds of precipitated iron oxide, goethite ("onion rings"). Again, precipitates concentrate the most where soil solution remained the longest, at the meniscus where two gravel stones touched (ie: the crater-like features on intact gravel coats)

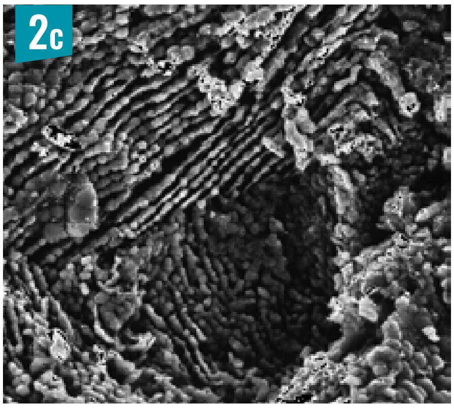


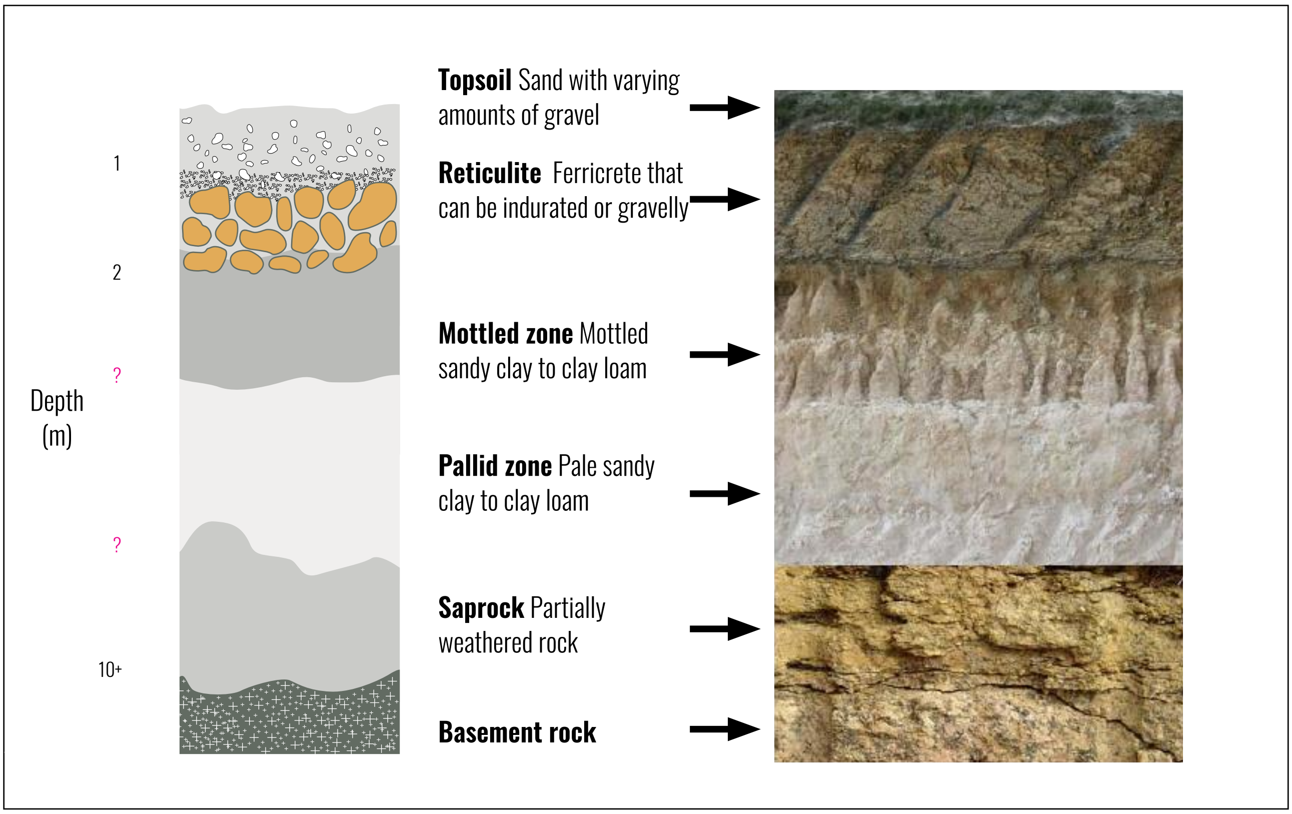
Figure 2c: Electron micrograph of surface coats of ironstone gravel

Bacterial involvement in precipitation of goethite in a gravel rind. Each string of spheres represents a coat of goethite. The void represents a pore in gravel that permits the flow of water to the interior of the gravel.

DUPLEX SOIL

Laterisation is a biological process requires a leaching environment, a source of iron and aluminiumis of widespread importance in soil development, soil properties and hydrogeology of the wheatbelt with the typical laterite profiles (Fig 3) most common. There are a number of factors required for lateritic formation including fluctuating watertables, leaching and biological activity within native plant roots (Verboom and Galloway (2004)). The pallid or 'piped' clays have extremely low hydraulic conductivity and high salt storage.

Fig 3: Diagrammatic representation of a lateritic profile.



GROUNDWATER CHARACTERISTICS

ANCIENT DRAINAGE ZONE

Hydrology is influenced by the low annual rainfall, subdued landscape and relatively deep weathering profile (from 20-60 m). Local relief is often less than 40m, slope gradients are usually less than 5% and valley floor gradients are less than 1%.

Annual surface runoff is low, around 20mm (approx 4% of rainfall) and is due to a combination of gentle slopes, sandy surfaced soils and sluggish drainage lines. Water only flows in drainage lines during winter resulting in nil to minimal baseflow occurring outside of the winter period. The exception to winter flow is the occasional summer thunderstorm resulting in some flow.

The broad valley floors act as a sump for water and salt, which accumulate in lakes and depressions (Fig 4). Average salinity of surface runoff is 4,500mg/L (820mS/m - brackish). The main storage areas for surface water are large circular lakes which have formed on the broad valley floor (eg Lake Dumbleyung).

Groundwater recharge is low due to the low rainfall however the rate of rise has increased from 0.2mm/yr to the current rate of 10-50mm/yr. Recharge occurs throughout the landscape via gravel and sandy soils on broad hill crests and divides. The broad valley floors can also act as recharge areas depending on seasonal conditions.

Aquifers are found in both the saprock and pallid zone of the lateritic profile and are typically dominated by intermediate flow systems. The saprock aquifers are typically 0.5-5.0m thick and are semi-confined or unconfined by the overlaying pallid zone therefore most of the lateral groundwater flow occurs in these aquifers. Lateral groundwater flow velocities are slow, generally 0.01-2mm/yr. Small amounts of water are contained in fractured rock aquifers below the lateritic profile. Sandplain seeps occur at the break of slope or where sand thickness thins out on slopes with deep sands.

Aquifers in the sedimentary deposits on the valley floors may be surficial, semi-confined or confined.

Temporary perched groundwater forms in sandy topsoils during wet years (approx 4-5 yr in 10).

Groundwater salinity ranges from 54–5500mS/m) (from fresh to extremely saline) with water levels rising at 5-50cm/yr.

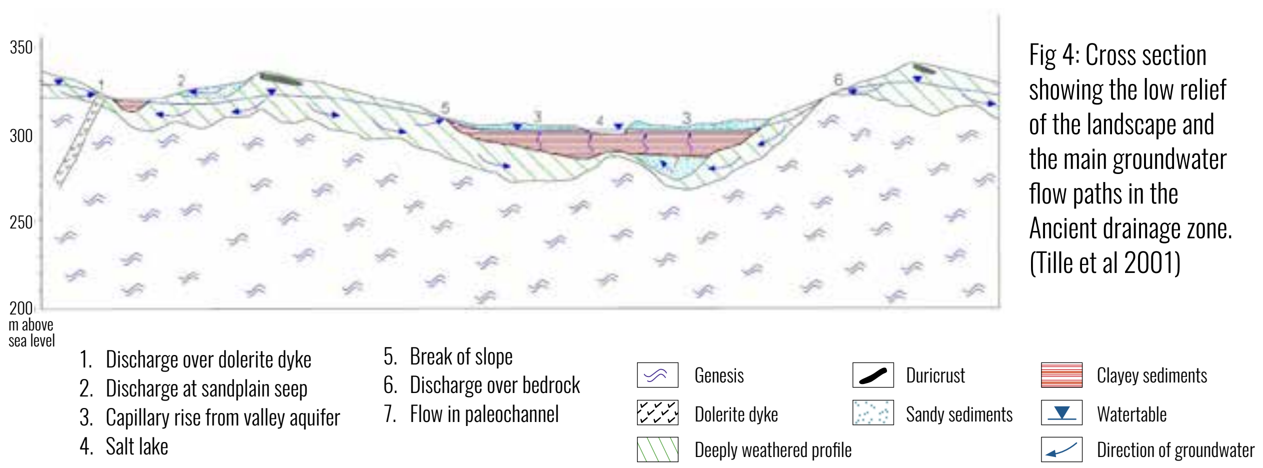


Fig 4: Cross section showing the low relief of the landscape and the main groundwater flow paths in the Ancient drainage zone. (Tille et al 2001)

REJUVENATED ZONE

Hydrology is influenced by higher surface runoff, approx 40mm yr (8% annual rainfall) which flow in major rivers each winter. Average stream salinity is 650 mS/m (3,500mg/L; brackish) and is increasing at a rate of 50-90mg/L/yr. (RM Tech Report 243). Water in minor drainage lines can be fresh to marginal but is typically brackish to saline. Most of the flows occur in winter with minimal baseflow. However, as you get closer to the Darling Fault baseflow occurs more frequently and for longer periods. Water storage is in lakes on the boundary of the ancient drainage zone, many were originally fresh but are becoming saline. Many of the smaller lakes become dry over summer.

Groundwater recharge rates range from 10-100mm/yr and occur throughout the landscape.

Aquifers are found in the saprock and pallid zone of the lateritic profile or its remnants. Valley floor sediments also contain aquifers with only small amounts of water in fractured rock below the lateritic profile (Fig 5). Groundwater movement is dominated by local flow systems. Intermediate flow systems occur in the sediments. Lateral groundwater flow ranges between 0.02-5 mm/yr in the saprock with hydraulic gradients upto 1.5%. These flow rates are higher than in the ancient drainage zone and can be attributed to the increase dissected nature of the landscape.

The relatively shallow regolith (<40m) results in less severe discharge areas than those in the ancient drainage zone. Discharge from local flow systems can be extensive (>10ha in size) and is usually associated with dolerite dykes, bedrock highs and break of slope seeps.

Groundwater quality is generally in the range 90 – 2000 mS/m (fresh to saline) although levels up to 3000 mS/m (saline) can occur deeper in the regolith profile.

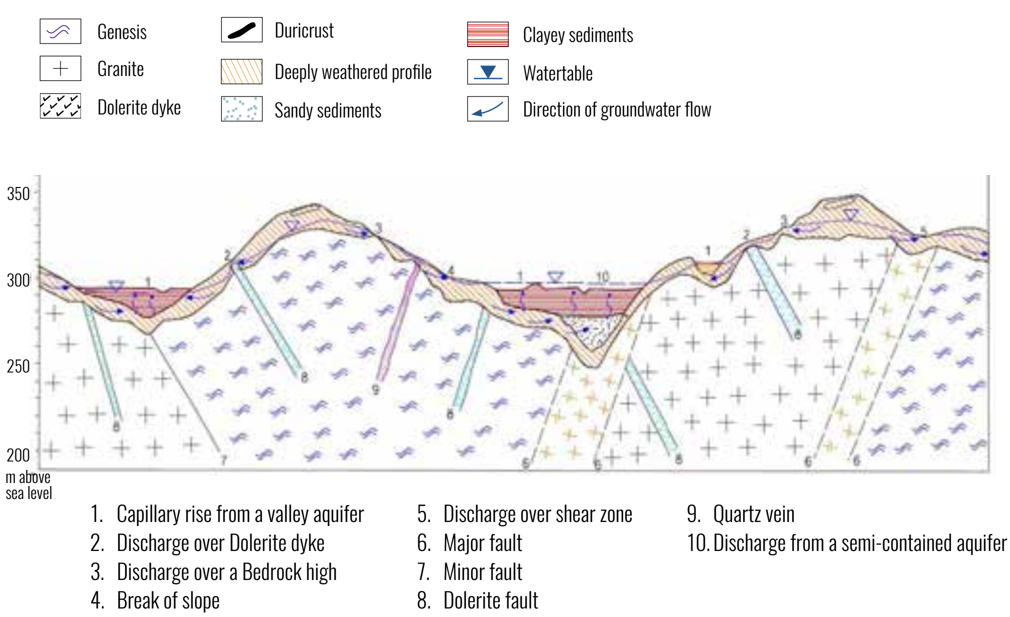


Fig 5: Cross section showing the dissected landscape of the Rejuvenated zone with geological features and groundwater flow paths. (Tille et al 2001)

COASTAL PLAIN

Hydrology is influenced by the moderate to high rainfall, flat topography and recharge from the Perth sediments. Annual surface runoff ranges from 0mm (sand dunes) to 330mm (30% annual rainfall) on clay flats. While major rivers such as the Avon, Serpentine and Collie cut through the Plain, a lot of stream flow occurs in artificial drainage channels. Baseflow occurs all year round. Swampy depressions are common and drainage can be sluggish due to low relief.

Groundwater is stored in surficial aquifers in the Quaternary sediments and the underlying confined aquifers of the Perth Basin (Fig 6). Perched groundwater is widespread in the surface horizon of the sandy and loamy duplex soils in the winter months. The Guilford formation is a surficial aquifer approx 5-50m thick and fluctuates with seasonal conditions.

Groundwater salinity in the surficial aquifers ranges from fresh to marginal (<1,000mg/L) (fresh) but can be up to 25,000mg/L (saline) if they are impacted by salt water intruding from the coast.

Groundwater movement is dominated by regional flow systems with discharge from the Leedeville formation some 100km away from the recharge area.

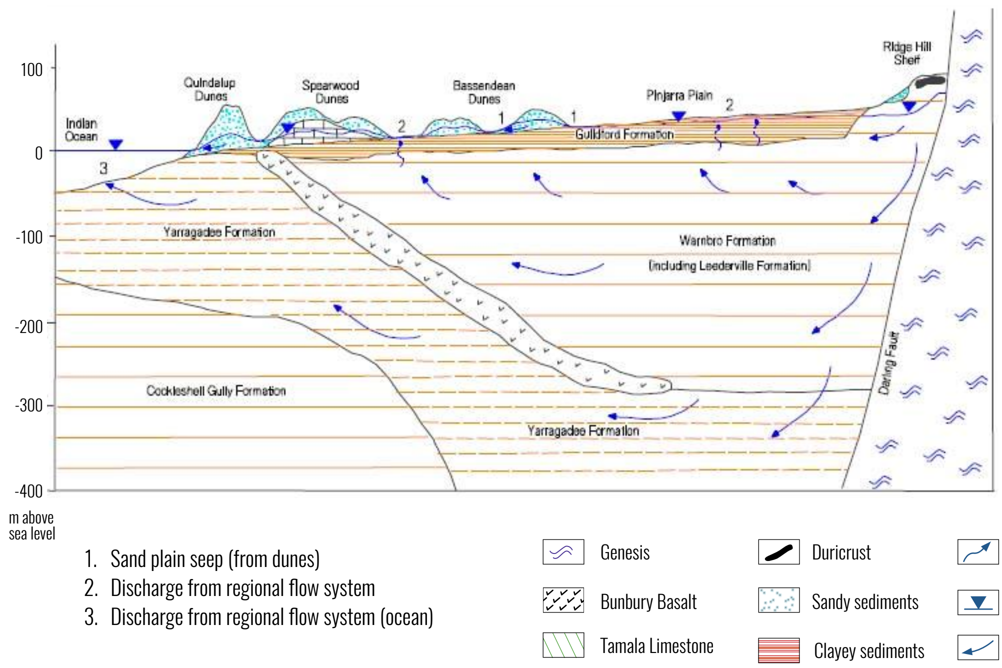


Fig 6: Cross section showing the flat landscape and dunes of the Coastal zone with surficial and regional aquifer flow paths. (Tille et al 2001)

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QUESTIONS

1. Why can the region be divided into 3 distinct drainage zones?
   - ❑ The Darling Fault is causing a problem by slowing down drainage to the ocean.
   - ❑ The region has the largest linements.
   - ❑ Axis, Faults and uplifts have had a impact on the surface topography resulting in different drainage line structure.

2. Why does the Ancient Drainage Zone have large lakes?
   - ❑ It is part of the Yilgarn Craton which is bounded by the Meckering Line resulting in low relief with valley floor gradients of less than 1%.
   - ❑ They are needed to store water and salt.
   - ❑ It doesn't rain often so lakes keep water in the catchment for future use.

3. What are laterites?
   - ❑ A term used to identify biological activity.
   - ❑ Soils in which iron and aluminum accumulate to produce gravels.
   - ❑ A soil profile containing Pallid zone clay.

4. The process of laterisation needs a number of factors. What are they?
   - ❑ Fluctuating water tables, leaching and biological activity.
   - ❑ High salt storage, sand and water.
   - ❑ Iron, pressure and high rainfall.

5. Are groundwater characteristics influenced by rainfall, topography and groundwater slope gradient?
   - ❑ Yes, all these characteristics can have an impact on groundwater behaviour.
   - ❑ No, only some of the characteristics.
   - ❑ Maybe, as it depends on which drainage zone you are in.

NOTES

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