PRODUCTIVE SALTLAND PASTURES

Salinity Manual

Module 7

Infiltration, leakage & recharge

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA
natural resource management program

INTRODUCTION

INFILTRATION

Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate is a measure of the rate at which soil is able to absorb rainfall. It is measured in millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate (rainfall) exceeds the infiltration rate, runoff will usually occur.

Infiltration is governed by two forces: gravity and capillary action or absorption. While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even against the force of gravity.

The rate of infiltration is affected by soil characteristics and water repellence including ease of entry, storage capacity, and transmission rate through the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates of any vegetative types.

Once water has infiltrated the soil beyond the plant root zone it remains in the soil as un-saturated soil moisture and over a period of time percolate down to the saturated zone (ground water aquifer).

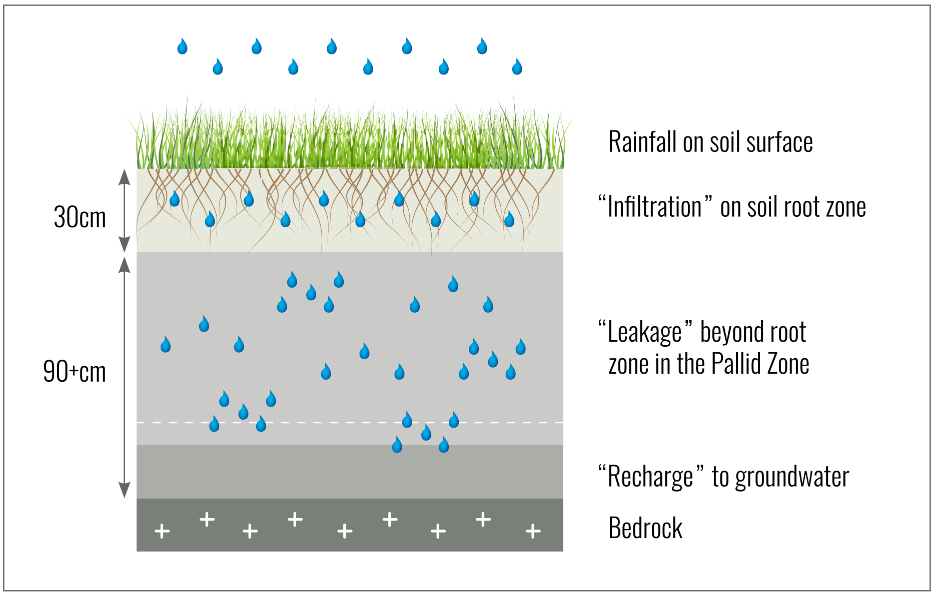

Fig 1: Conceptual diagram showing ‘leakage’ process in the soil.

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RECHARGE

Recharge is the result of movement of water past the root zone and into the groundwater system. Excessive recharge adds water to the groundwater system and will cause the watertable to rise. Salinity is largely attributed to this process. The amount of recharge occurring in a landscape depends on soil, geology, vegetation and climate. Land management plays a significant role in recharge management.

It is estimated that under natural vegetation in the 350-400 mm rainfall zone the long term amount (0.01 - 1.0 mm per year) of recharge occurs and can be described as being the natural equilibrium. This is averaged over decades and reflects averages of very wet episodic periods too.

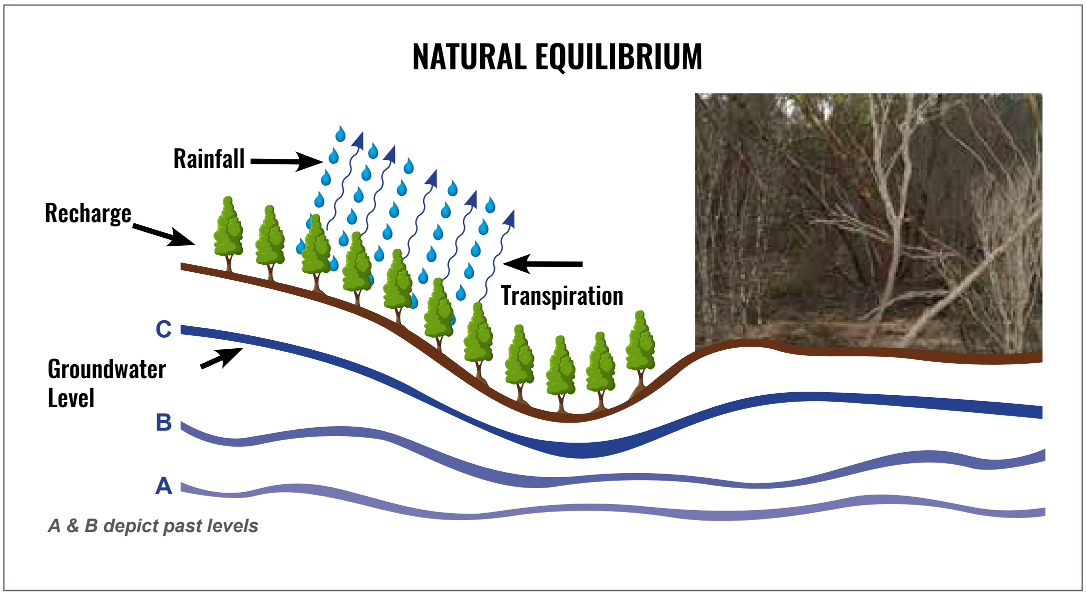


Fig 2: Conceptual diagram of watertable in natural equilibrium.

Compare this to where the natural vegetation has been replaced with annual plants and the recharge is significantly higher (6 - 65 mm per year) for the same rainfall zone and occurs naturally. Eventually over a period of time the water table rises to reach a new equilibrium. If groundwater is very close to the soil surface, recharge may not occur and excess rainfall may change to runoff.

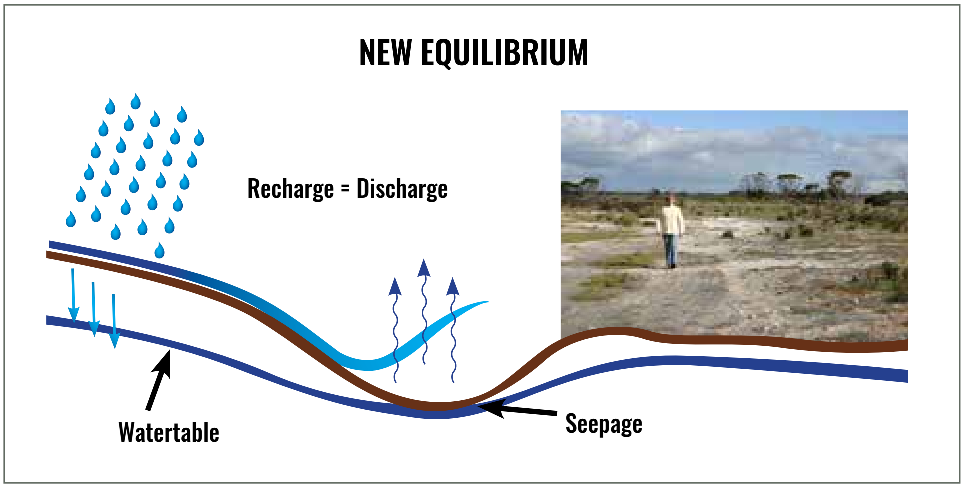


Fig 3: Conceptual diagram of watertable in new equilibrium.

With the change to a new equilibrium, new discharge areas are formed or existing ones become saline resulting in secondary salinity. This is a situation where the salinity levels (of soil and water) increase because of human activities changing the water balance. Key factors to consider are that recharge is generally a catchment-wide process and the rate of recharge varies significantly.

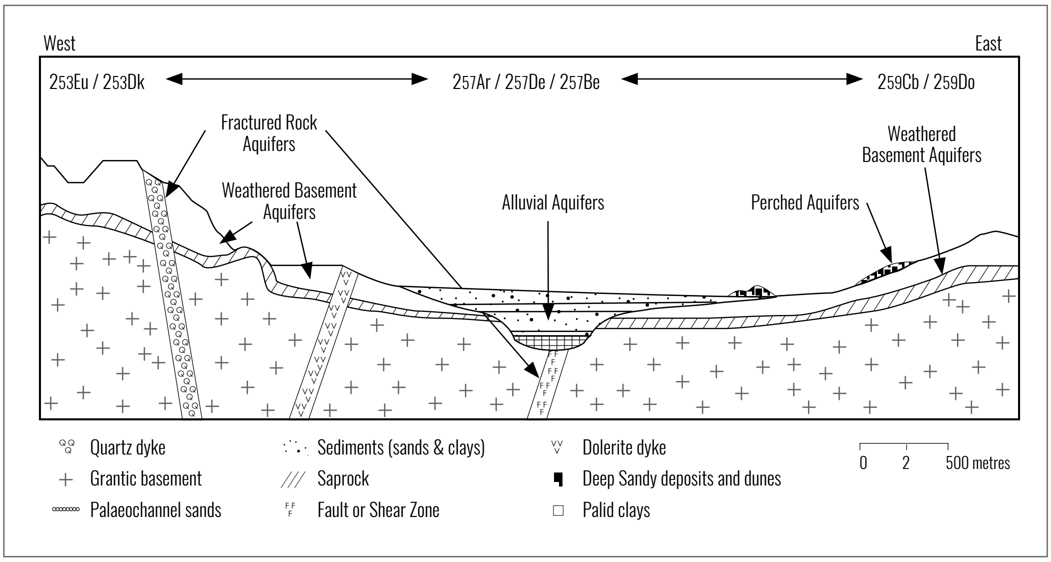


Fig 4: Cross section showing aquifers found within the Hillman and Narrogin Zones. (Tille, P. et al 2001)

Figure 4 shows a cross section of an area within the Hillman and Narrogin Zone with various types of aquifers and their likely position in the landscape. Key factors to consider are that recharge is generally a catchment-wide process and the rate of recharge and groundwater flow varies significantly. Recharge is measured as hydraulic flow which occurs either through a perched water table, paleo-channel sediments or at depth in the saprolite (coarse weathered rock material). The flow rate is relatively high in the saprolite (0.75m/day) whilst in the pallid clay the rate of hydraulic flow is reduced and restricted by the fine textured clay (0.01m/day) Table 1.

Table 1: Hydraulic conductivity values (m/day) for a number of geological units and aquifer types.

GEOLOGICAL CLASS	AQUIFER TYPE	K_{sat} (M/DAY)
Granite saprolite	Saprock	0.75
Granite pallid zone	Weathered basement	0.09
Mafic/intermediate dykes saprolite	Fractured rock	0.68
Mafic/intermediate dykes pallid zone	Weathered basement	0.20
Major faults saprolite	Fratured Rock	3.08
Major faults pallid zone	Weathered basement	0.53
Tertiary sand	Alluvial palaeochannel	3.61
Tertiary mixed		0.56
Tertiary clay		0.01

Source: SW NRM Region Appraisal Team

It is estimated that the current area of saltland (secondary salinity) in the South West Catchment is 55,650 hectares or 2% of agricultural land (Macfarlane, D.J. et al, 2004).

LEAKAGE

Leakage is a term used to quantify the amount (mm per year) or (percentage) of annual rainfall that 'leaks' beyond the plant root zone. This water eventually reaches the aquifer below resulting in watertable rise and potential threat to increasing secondary salinity. Leakage can be estimated for a range of land use options over a number of common soil types for the region. The Department of Agriculture and Food of Western Australia have developed a 'leakage calculator' to help farmers and their advisors quantify the amount of water leaking past the root zone of agricultural plants with a view to tailoring recharge minimising strategies for salinity management.

Table 2 illustrates the results of comparing various landuses on a representative farm in Kojonup (Great Southern) with an average rainfall of 502mm. The farm is 2,500ha with 1,150ha crop, 370ha lucerne and 160ha treed. The estimated leakage is for each soil unit and landuse is classified from low (green) to high (red).

Table 2: Estimated annual average leakage from a representative farm in Kojonup, green highlights areas with low leakage while red areas have high leakage.

Land Management Unit	LEAKAGE (mm/yr)						
	C	P	Se	G	Lu	E	S
Sandy gravels	28	31	31	5	3	0	5
Deep sands	55	57	56	36	16	12	18
Deep sandy duplex	29	31	30	5	5	2	8
Shallow duplex	17	17	17	3	2	0	4
Sandy loams	13	13	13	2	1	0	2
Red soils	18	20	19	10	1	0	3

Max. leakage rate: **57** mm

Leakage is colour coded

- High Leakage - greater than 5% of MAR or greater than 10% of MAR for permeable soils
- Moderate Leakage - 2.5% to 5% of MAR or 5% to 10% of MAR for permeable soils
- Low Leakage - less than 2.5% of MAR or less than 5% of MAR for permeable soils

Legend:

C=Crop; **P**=annual pasture; **Se**=serradella; **G**=perennial grasses; **Lu**=lucerne; **E**=Eucalyptus; and **S**=saltbush.

MAR = mean annual rainfall (mm)

The amount of leakage is rated as being high, medium or low, based on the total mm leakage and soil type. If the leakage on a soil is low, a small amount of water will eventually reach the aquifer whereas high leakage results in more water draining down to the aquifer. As can be seen in the example, the total mm of drainage coming from different parts of the farming system are based on soil types and cropping rotations.

Leakage estimates based on rainfall and soil types is useful as it illustrates the difference in water use from a range of crop and pasture rotations. This can provide an assessment of recharge from a paddock, farm and catchment perspective.

The figures for leakage as a 'percentage' of annual rainfall are only an indication based on average season's rainfall and standard crop and pasture parameters. It is useful to use these figures and compare the relativity between rotations and soils but should not be used as actual leakage. In low rainfall years leakage will be reduced and may even be low under pasture; in high rainfall years even the perennials can not use all of the rainfall immediately. The main difference in leakage is between bare soil, annual crops and pasture, and perennials. The differences in water use between annual crops or pasture are generally quite small in comparison and will vary from year to year. No annual crop is likely to be significantly better or worse than another. However, failed crops and bare soil will have significantly higher leakage.

Saltbush in alleys and pasture cover in the inter-row on this saline site in Yealering WA has off-set the on-site leakage to the groundwater and maximised grazing production.

FACTORS AFFECTING LEAKAGE

SOIL EFFECTS

Soil water holding capacity or 'field capacity' is the amount of water retained by the soil at the plant-root-zone after leakage occurs. The maximum amount of water retained is potentially less in soils with a high soil water holding capacity, as larger volumes of water can be stored in the root zone and used by plants. Soil water holding capacity is influenced by soil texture and depth of root zone, as well as soil structure.

The ideal soil structure is achieved by ensuring high organic matter content and minimal compaction. Leakage may be influenced by soil texture and its associated permeability. Coarser textured soils tend to be more permeable and potentially more 'leaky' than fine textured soils (Fig 5). Poorly structured sodic soils and soils with low pH may have low permeability and may lead to waterlogging surface ponding or perched groundwater.

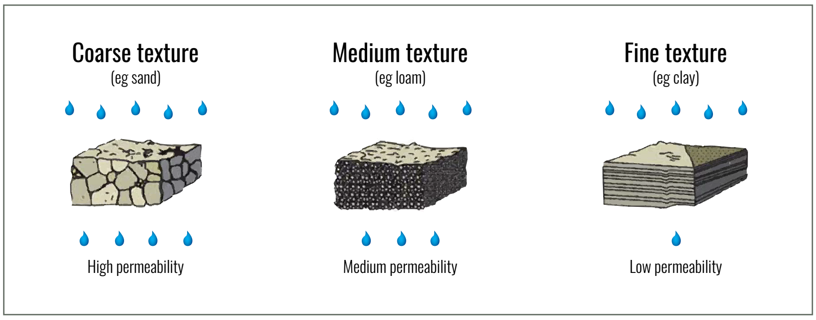


Fig 5: The permeability of different soil textures influences leakage rate to the groundwater system (Gill 2002).

GEOLOGICAL FACTORS

The geology of an area is associated with soil formation. A uniform soil type with no change in clay content down the profile will have uniform flow characteristics. However, when soils are formed and pushed up via faults and shifts, the resultant regolith behaves very differently from a uniform one. Geological factors to consider are thickness of the regolith, soil type, layering, overprinting, bedrock highs, paleo-channels, lakes, hinge lines, faults, shear zones, dolerite dykes and type of basement rock.

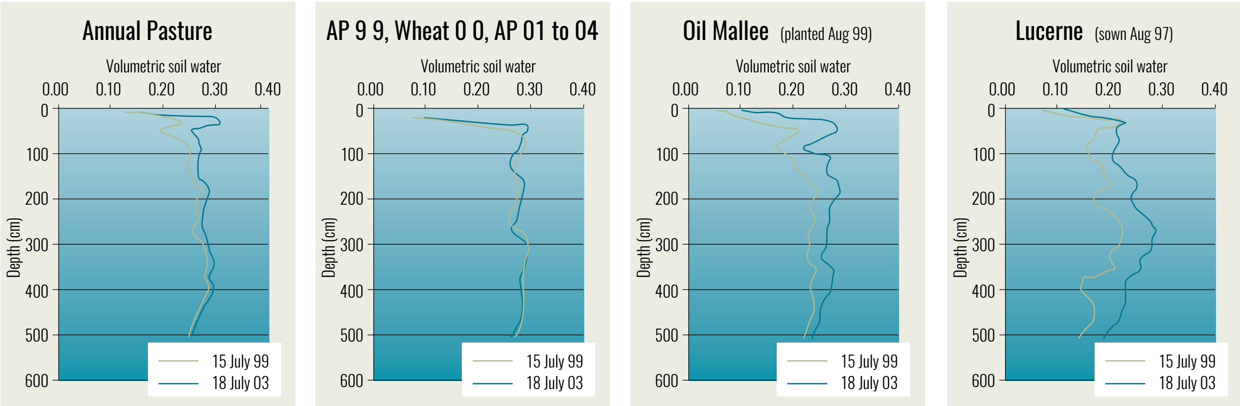
VEGETATION EFFECTS

Vegetation has a significant impact on recharge and can be managed to reduce leakage, either where the rain falls directly or where water accumulates in depressions or discharges at the break-of-slope and broad valley floors.

Selecting plant species according to their perenniality, growing season, root depth zone, salt tolerance and adaptation to local conditions can maximise water use and reduce leakage.

Lucerne, probably the most widely sown perennial, is currently grown on approx 80,000ha of agricultural land.

Perennial plants that are deep rooted will reduce recharge to the watertable as they have the potential to use water over a greater part of the year and dry out the soil to a greater depth than annual vegetation (Fig 6).



- Annual pastures dried the profile to 0.9m thereafter no change was observed
- 85mm soil moisture was extracted from 0.5m profile

- Wheat dried the profile to 0.7m thereafter no change was observed
- 80mm soil moisture was extracted from 0.5m profile

- Oil mallee dried the profile to 1m thereafter no change was observed
- 120mm soil moisture was extracted from 0.5m profile

- Lucerne dried the profile to 3.3m thereafter small change was observed
- 265mm soil moisture was extracted from 0.5m profile

Fig 6: Diagrammatic image of soil moisture profiles for annual species and perennial species show differences in the ability of each to use soil moisture. Lucerne created the largest dry soil buffer (265mm) compared with annual pasture (80mm).

Summer active perennial plants such as lucerne; dry the soil profile in the period leading up to winter. A dry soil profile prior to winter can store more winter rainfall and act as a buffer to leakage past the root zone. (Ferdowsian, et. al. 2002).

Groundcover is vitally important to reduce surface run-off especially in summer dominant rainfall areas. When groundcover is low, storms with high rainfall intensity can lead to large amounts of run-off and soil erosion. Vegetation systems with summer and winter growing components (including legumes) are more likely to maintain a dry soil buffer year-round, while providing ideal groundcover.

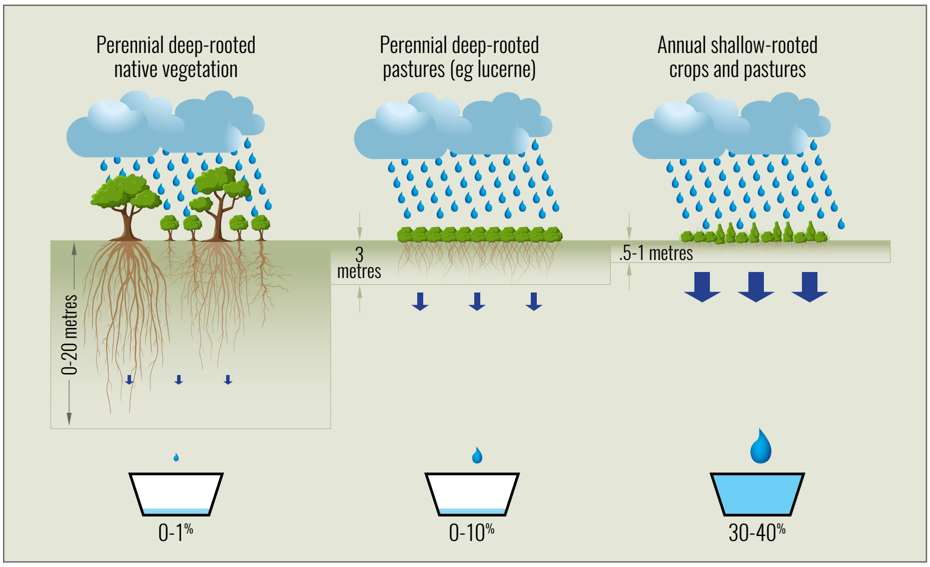


Fig 7: Diagrammatic comparison of rooting depth and leakage for 3 different landuses.

Plant water use is highest when plants are actively growing and as a result the soil profile is kept relatively dry. It is useful to grow winter and summer active perennials as the best recharge reduction strategy.

Perennial vegetation that is both deep rooted and active in summer can reduce leakage as it has a greater potential to dry the soil profile over a longer growing season compared with annual vegetation (Fig 7). Dryland Lucerne, kikuyu grass and fodder shrubs including tagasaste (Tree Lucerne), saltbush, bluebush and Acacia saligna (fodder wattle) are some examples of perennial species which have changed pasture composition of existing annual species.

Valley floors planted to perennials shrubs and pasture species will reduce significantly the in-situ recharge and enhance groundwater salinity management.

IRRIGATION EFFECTS

Irrigation salinity involves the same process as dryland salinity. Both result from excess leakage of water past the plant root zone adding to the groundwater system and causing the watertable to rise. Recharge rates in irrigation areas can be much higher than dryland areas due to leakage from both rainfall and irrigation. Factors such as irrigation layout and management practices, soil type, the quality of water applied, and climate greatly influence the development of irrigation salinity.

A study of 20 irrigators in the Peel-Harvey region showed that 10% were applying water at the recommended efficiency while 90% could improve their water use efficiency (Milani, S). Apart from increasing the potential for recharge and surface salinity, leaching of nutrients to the aquifer and to large surface water bodies can result in algae blooms.

Irrigation salinity can also result from under irrigation and poor water distribution. Poor irrigation layout leads to poor water distribution which results in some areas being under irrigated, causing salts to accumulate, and other areas being over irrigated, causing waterlogging.

Salts are found in surface water and groundwater. When applied in irrigation water, the salt remains behind in the soil as water is taken up by plants or lost to evaporation. Periodically, it may become necessary to leach these salts to avoid them accumulating in the plant root zone to levels that impact on productivity. Measurements from a irrigation property in Benger showed that in 1999 15t/ha of salt was applied via the irrigation water with 10t/ha being flushed off site and 5t/ha accumulating in the soil (Dairy Note No 9).

Over time, continual under-irrigation (insufficient water to leach the salts below the root zone) can result in salts accumulating within the plant root zone. Poor drainage or less permeable layers in the profile limit the ability of the water to drain away and can cause a local or perched watertable to develop. This results in both water and salt being held in the plant root-zone for extended periods of time. Groundwater mounds can occur under irrigation areas, putting pressure on the regional groundwater system, forcing saline groundwater into waterways.

CLIMATIC EFFECTS

The potential for recharge to the watertable is greater in 'wet periods' when rainfall exceeds evaporation. A region's climatic conditions of temperature and precipitation influence water volume and movement within a landscape and are an important factor in identifying salinity risk areas.

In high rainfall areas, which are also close to the ocean, historical recharge has been more than that in low rainfall areas. Hence aquifers have developed in response to the high historical recharge. Consequently the rate of recharge may have increased since clearing but the regolith has the ability to accept and drain this extra water out of the system. However in the low rainfall zones, historical recharge has been low and even a small increase in recharge results in groundwater rises due to the inability of the aquifer to cope with the extra amounts.

Rates of groundwater level rise have been reduced with a decline in annual rainfall as has been observed in many parts of the agricultural region (George et al 2008).

See DPIRD interactive salinity map tool.

Climatic variation and rainfall dominance (either summer or winter rainfall) can have a long-term effect on recharge. Figure 8 shows a map of the Western Australian agricultural area with the rainfall isohyets at 100mm gradients and includes graphs of monthly rainfall and potential evaporation averages (1976–2008) for twelve geographic locations. The relationship between average monthly rainfall and evaporation has important consequences for understanding recharge and the land use options to manage it.

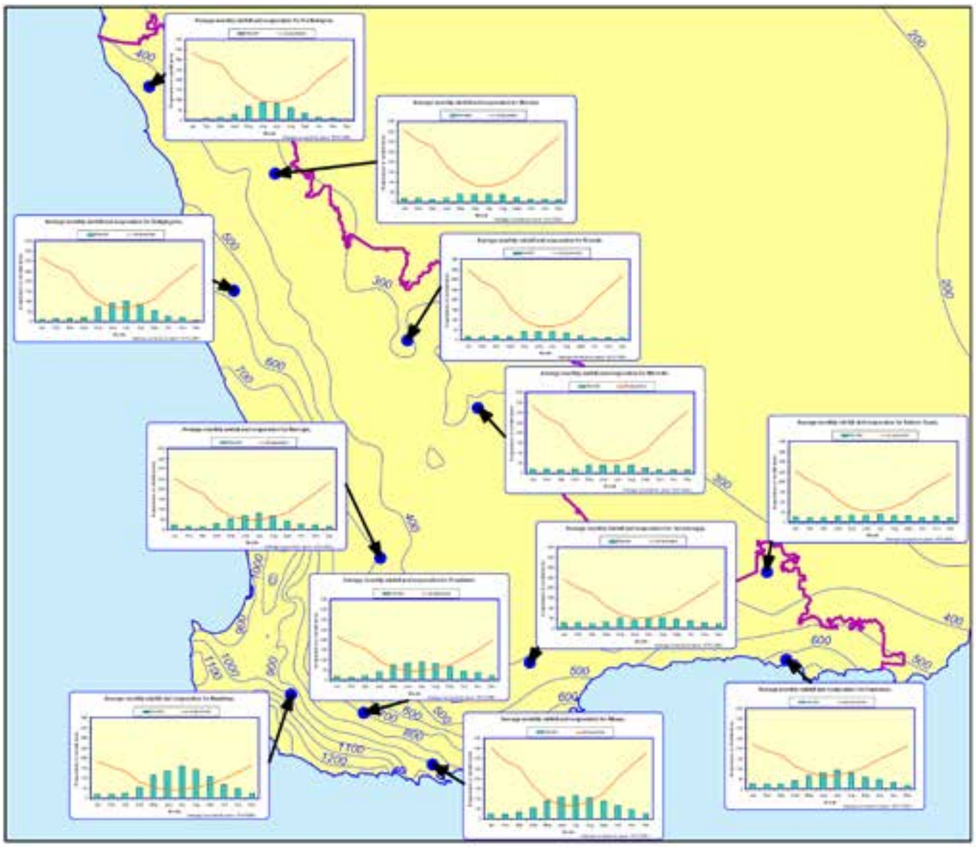


Fig 8: Rainfall distribution and evaporation graphs for various places throughout the agricultural zone.

Summer storms, often associated with cyclonic events from the north west of the state contribute greatly to the total rainfall. As a result episodic recharge occurs (sudden rises; stablise and then jumps again), and is the cause of groundwater level rises in low rainfall zones districts.

Lewis et al. (2000) showed the importance of understanding episodic recharge impact on aquifers. They calculated that just 10% of annual recharge events contributed to over 85% of long-term total recharge. These recharge episodes were caused by high rainfall events and occur at irregular intervals. This means you could have a period of little or no recharge and then a 6 month period with recharge of up to 30 to 50mm. When this occurs to aquifers in the Ancient drainage zone groundwater levels usually do not fall back to their pre-episodic event levels while in the rejuvenated zone aquifers have some ability to fall again.

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Leakage calculator
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QUESTIONS

1. Infiltration rate is a measure of:
   - ❑ the amount of rainfall not used by plants
   - ❑ the ability of different soils leak water to the aquifer
   - ❑ the rate at which soil is able to absorb rainfall

2. Recharge is:
   - ❑ the movement of water past the root zone to the groundwater system
   - ❑ when watertables rise
   - ❑ the landscape needs renovation

3. What is leakage?
   - ❑ a zone where groundwater travels quickly
   - ❑ the amount or % of rainfall that leaks beyond the plant root zone
   - ❑ when plant roots cannot use groundwater

4. How do perennials reduce recharge?
   - ❑ The roots penetrate the soil profile deeper, providing the ability to use more moisture than annuals and hence lower the chance of leakage.
   - ❑ They provide high quality feed for stock.
   - ❑ They grow fatter roots and more green leaves.

5. Why is it important to know what a Episodic recharge event is?
   - ❑ It only happens once every 5 years so it isn't important.
   - ❑ Infiltration rates decrease and aquifers don't flow as much.
   - ❑ Because recharge can occur in one or two large rainfall events rather than spread throughout the year and therefore cause a large sudden rise in the water table.

NOTES

PRODUCTIVE SALTLAND PASTURES

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