Book 1 Dryland Salinity: The Basics

Introduction

Dryland salinity is the cause of serious land and water degradation in many parts of Australia. A complex range of biophysical factors contribute to dryland salinity. The distribution and combination of these factors varies enormously across the landscape; a situation that has historically presented problems in understanding and managing salinity.

The ancient, flat and arid nature of much of the Australian continent predisposes it to salinisation. Human activities can also affect the biophysical equilibrium that dictates whether salinity will occur.

It is possible to gain a much better understanding of the dryland salinity process by examining the individual factors that contribute to it. Through understanding each component of the process, effective and economic salinity management options can be selected. Targeted management based on sound understanding of processes will enable both the symptoms and the causes of dryland salinity to be addressed.

This booklet is designed to help you understand the basic processes and impacts of dryland salinity. The other booklets in this series provide more detail on specific aspects of dryland salinity and its management.

1. What is salinity?

Salinity is the accumulation of salt in land and water to a level that impacts on both the natural and built environments. The impacts of salinity can affect native plants and animals, aquatic and terrestrial ecosystems, agricultural crops and pastures, water supplies and infrastructure such as roads and buildings.

Salinity occurs naturally in many parts of Australia because of a combination of biophysical conditions. In particular:

- a geological and climatic history that has generated and stored high levels of salt;
- its present day arid climate and relatively flat landscape which promote salt accumulation and concentration in specific areas; and
- long-term climate trends driving changes in groundwater levels and salt mobilisation.

Salinity is a process inherent in the Australian landscape; however, human activities have accelerated the process of salt mobilisation and accumulation. Salinity is often classified into several different types based on the broad cause as described below.

Dryland salinity

Dryland salinity occurs in all non-irrigated areas due to rising groundwater. It includes both naturally occurring salinity and salinity resulting from increased recharge and/or reduced discharge under dryland farming systems. Dryland salinity may also occur following soil erosion causing exposure of saline sub-soils.

Irrigation salinity

Irrigation salinity occurs when the increased recharge and rising groundwater is due to the application of large volumes of irrigation water and leakage from channels and storages.

Urban salinity

Urban salinity refers to areas of the built environment showing symptoms of salinity. In urban areas the increased recharge and rising groundwater are caused by activities such as clearing of vegetation for development, over-irrigation of gardens and public parks, inappropriate stormwater discharge, disruption of natural drainage lines and leakage from water pipes and swimming pools.

Industrial salinity

Industrial salinity results from processes that accumulate and concentrate salt in industrial wastewater. The sources of salt include urban effluent, agricultural chemicals and wastewater from mines and power stations. This saline water can be a pollutant if it is released or leaks into watercourses or groundwater inappropriately. These sources are often monitored to allow appropriate and timely action to minimise their effects.

2. The development of dryland salinity

Changes in the water balance

Dryland salinity can occur when the water balance in the landscape is changed and salt is mobilised by groundwater as it rises to the land surface. Groundwater levels rise when the input of water to the groundwater system (recharge) exceeds the amount of groundwater leaving the system (discharge).

Water tables can rise following large inputs of water occurring naturally after successive wet seasons, decades, or centuries, or following significant reductions in water use caused by changes to the vegetation cover and its distribution. The removal of native vegetation and its replacement with agricultural crops and farming practices has resulted in significant change to the water balance in many areas.

If groundwater levels remain static, or rising, then salinisation will persist and may expand. To manage dryland salinity, groundwater levels must be lowered and the equilibrium between water inputs and outputs re-established.

The hydrological cycle presented in Figure 1 shows the main elements of the water cycle involved in the salinity process.

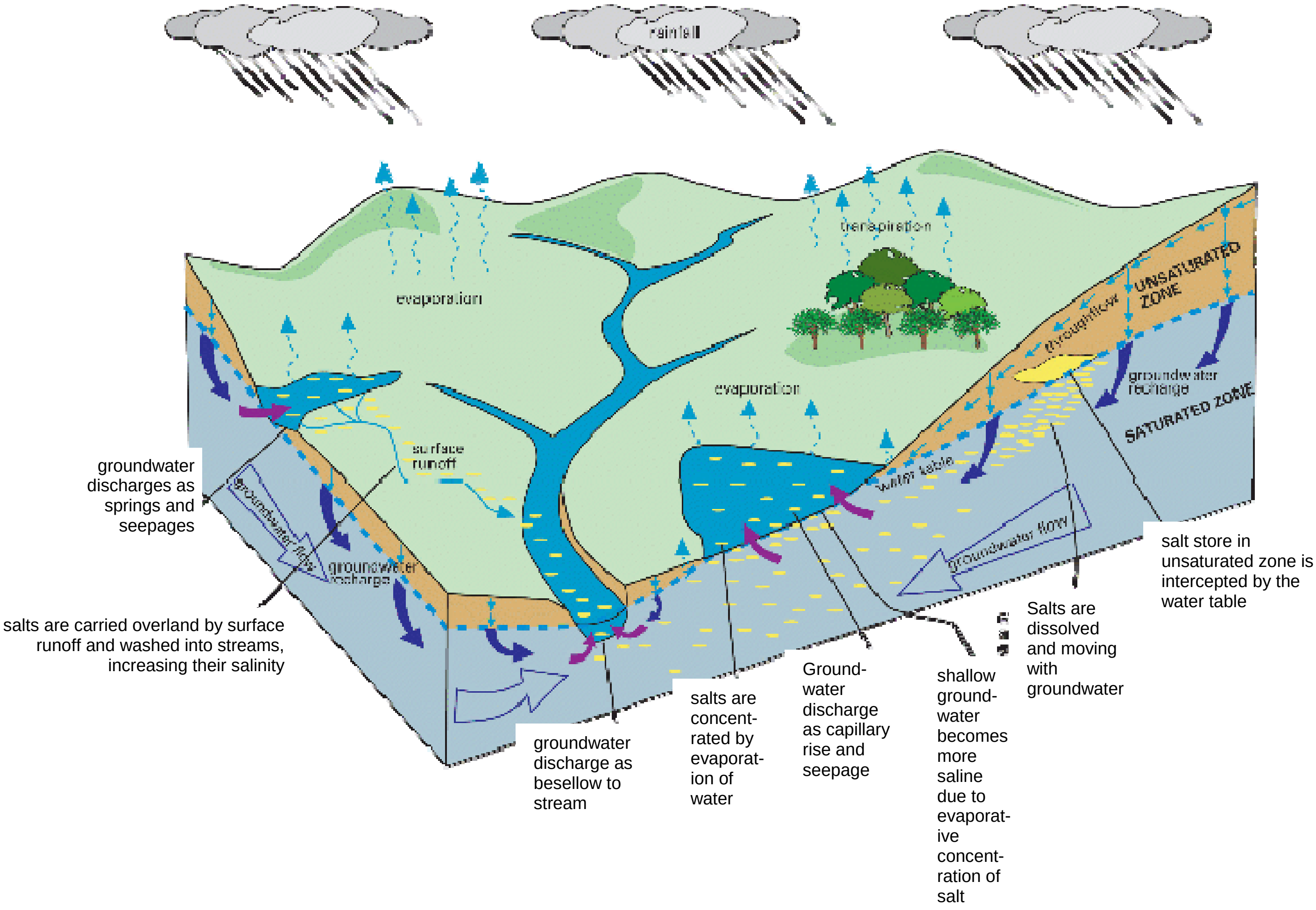


Figure 1: The hydrological cycle and salinity processes.

Changes in the type and distribution of vegetation

Native vegetation has evolved and adapted to survive in the Australian climate. Native trees, shrubs and perennial grasses create a "soil sponge" consisting of roots and healthy soil up to six metres deep. After prolonged rain, water fills this "soil sponge" until it reached its holding capacity, at which point any excess water leaks through the soil to the groundwater system.

The application of European farming systems in Australia has changed the distribution of vegetation types across the landscape, introducing new species to replace native species for production purposes. Annual crops and pastures such as wheat and clover have relatively small, shallow root systems and use water for only part of the year. In comparison, perennial native vegetation is deep rooted and requires water for growth all year round. Many natives also have the capacity to increase growth rates rapidly in response to rain events. Both of these characteristics of native vegetation limit leakage to the groundwater system.

European style farming activities have reduced the thickness of the soil sponge to one metre or less in many places. As a result, the water holding capacity of the soil has been reduced and more water is entering the groundwater system, causing the groundwater to rise.

Landscape salinisation and degradation

Rising groundwater can mobilise salts stored in a previously unsaturated part of the ground. These salts are then concentrated at the ground surface as water evaporates. The water table does not need to reach the land surface to cause dryland salinity. When groundwater levels reach a critical depth of around one to two metres, water can be drawn to the surface by capillary action (Plate 1 and Plate 2).

Plate 1: Evaporative concentration of salt at the top of the capillary zone.

Plate 2: Salt concentration in soil by evaporative concentration of groundwater.

Initially, many plants suffer from the effects of waterlogging, as their roots can no longer take up oxygen. Gradually, the toxic effects of salt accumulation in the root zone also affect vegetation health. As the level of salinity increases, salt tolerant species begin to succeed those that are more salt sensitive.

Salinisation often includes high levels of sodium, causing the formation of sodic soils. These soils have poor structure and drainage capacity, and are highly dispersive and prone to erosion. Increasing levels of soil salinity and erosion of the topsoil makes it difficult for vegetation to survive, leaving soils bare and degraded.

The onset of erosion is rapid following the loss of vegetation and formation of dispersive soils. Sheet, rill, tunnel and gully erosion are commonly associated with saline areas. Ploughing, overgrazing, and disturbance of the soil by stock exacerbate the situation allowing heavy rainfall and high winds to trigger serious erosion.

Salts gradually accumulate on the ground surface through evaporative concentration during dry periods and are then flushed into waterways or back into the soil during wet periods. Streams, lakes, dams and shallow groundwater systems become increasingly saline. Shallow saline groundwater seeps into streams as baseflow during dry times, further increasing their salinity.

Effects of land management

Many of the land management practices with a high salinity risk were introduced and used when little was known about the relationships between biophysical elements and their impacts on the Australian environment.

The Murray Darling Basin is geologically and climatically prone to concentrating salt in the landscape . Landuse changes since European settlement have contributed to soil and water salinisation in the Basin.

Millions of tonnes of soil have been removed by wind and water erosion over the last 200 years as a result of some European-style land management practices now known to be inappropriate for the Australian environment.

More is now known about the long-term consequences of such practices and how to prevent them. Land managers are able to adopt integrated management approaches that are based on sound science and are more appropriate for Australian conditions. These new style integrated land management approaches will help improve the long-term viability and sustainability of agriculture, rural communities and the environment.

Appropriate land management practices are presented in later sections of this publication and are discussed fully in the publication entitled "Dryland Salinity - Productive Use of Saline Land and Water" in this series.

3. Factors contributing to dryland salinity

Climate, catchment shape, hydrogeology, soils and land use are important factors determining salinity hazard and risk for a particular landscape. It is possible to estimate the potential timeframe, severity and size of area that might be affected by dryland salinity by assessing these factors.

Climate

Arid climate **-** Rainfall is the main source of natural groundwater recharge. In climates where rainfall is much higher than the rate of evaporation salts are flushed through the landscape and carried back to the ocean by surface and groundwater flows and do not accumulate. However, much of Australia has an arid climate where the rate of evaporation greatly exceeds precipitation. Examples of precipitation and evaporation rates from across NSW are presented in Figure 2.

Because of the general excess of evaporation over rainfall, many places across Australia have the capacity for salt accumulation via evaporative concentration of shallow groundwater. Typically these areas have low annual rainfall and humidity, for example inland areas, and have a large difference between summer rainfall and evaporation. During the warmer months these areas have the greatest potential for evaporative concentration of salts to accumulate from shallow groundwater (Figure 2).

Long term climate change - In the same way that weather changes from day to day, the climate changes over decades, centuries and longer. Groundwater levels are strongly linked to climate, particularly rainfall. This relationship is shown in Figure 3.

As well as responding to daily and weekly rainfall events, the groundwater system responds, after some time lag, to previous years or decades of high or low rainfall. In Figure 3 it can be seen that over longer periods where annual rainfall was less than average, for example, from the years 1900 to 1950, groundwater levels also declined. Conversely, when annual rainfall was higher than average, from 1950 to 1990, groundwater levels followed a similar trend.

The time lag in the groundwater response depends on many factors such as timing and intensity of rainfall, geology, depth to groundwater, water storage and transmission, capacity of the groundwater system and land use.

Episodic groundwater recharge may occur in both summer and winter depending on location. The amount of recharge depends on how and when rain falls. Southern NSW experiences slightly winter dominant rainfall. Areas at higher elevations have much lower rates of evaporation but winter rainfall is high so there is a strong potential for groundwater recharge to occur. Northern NSW experiences slightly summer dominant rainfall. During particularly wet summer seasons, excess rainfall moves beyond the plant root zone and into the groundwater system.

Evaporative concentration of salt is more likely when evaporation is much greater than rainfall Summer rainfall is slightly dominant in northern NSW. In upland areas there is less difference between evaporation and rainfall in summer. On the inland plains of NSW evaporation is much greater than rainfall, especially in summer. Groundwater recharge is more likely when rainfall is higher than evaporation.

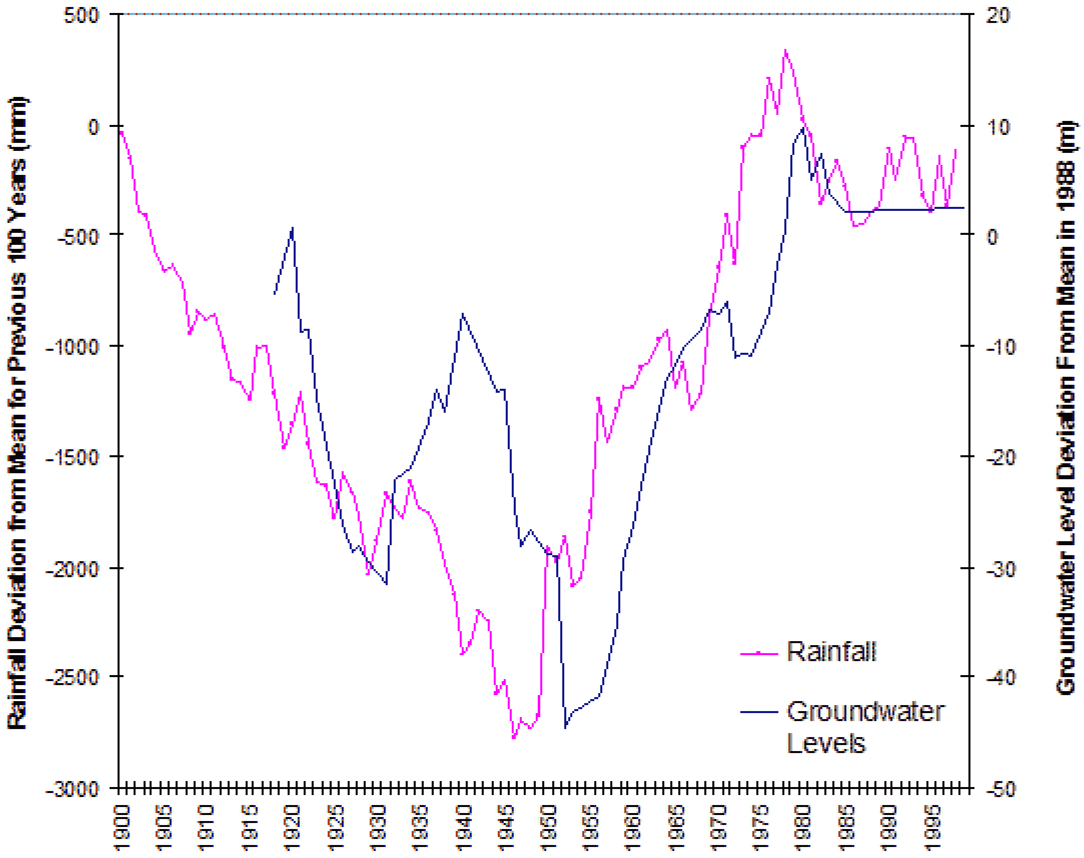


Figure 3: Relationship between rainfall and groundwater levels in Central NSW (Source: Salas and Smithson 2002).

Shape of the landscape

The shape and slope of a landscape are major factors determining whether salinity will occur within it.

Flat continent - Australia is a very old continent that has been exposed to erosion for a long period of geological time. Consequently, it has many large flat areas and generally low topographic relief. This means that the slope across the whole continent is low, so neither surface water nor groundwater flow very rapidly and, as a result, accumulated salts are washed away very slowly.

Catchment slope - At a smaller scale, surface water and groundwater drain more quickly in a catchment that has a steep gradient (Figure 4). Consequently, shallow gradients and restrictions such as vegetation growth in drainage lines can cause water to accumulate in the catchment. This water leaks down to the water table causing groundwater levels to rise (Figure 5).

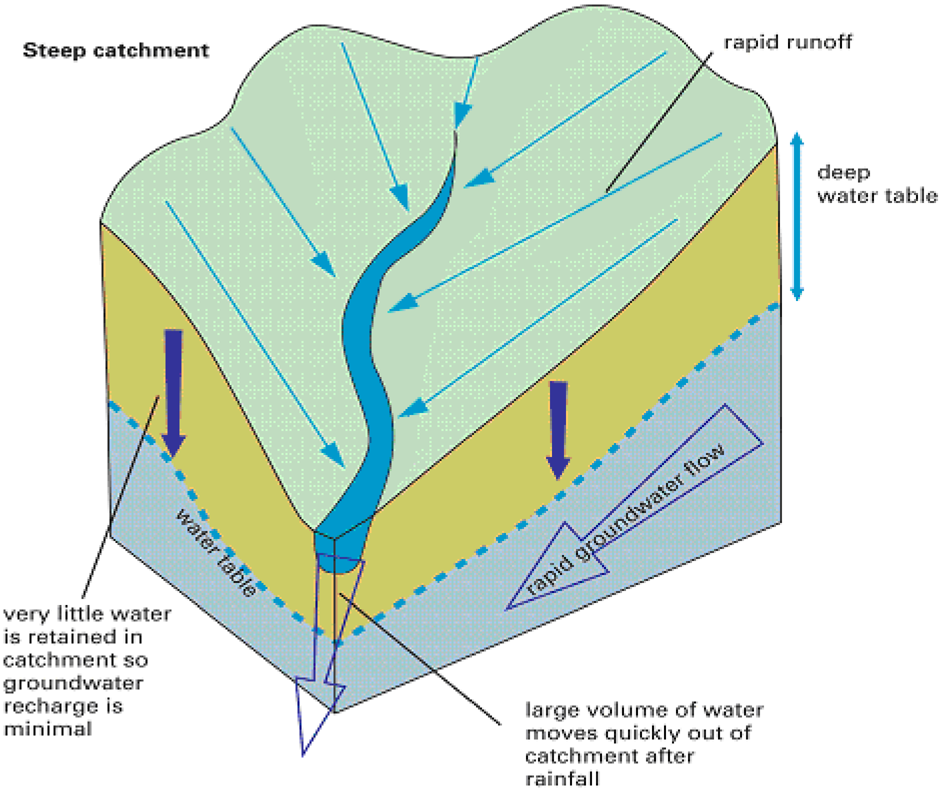


Figure 4: Catchment with steep gradient and rapid water drainage.

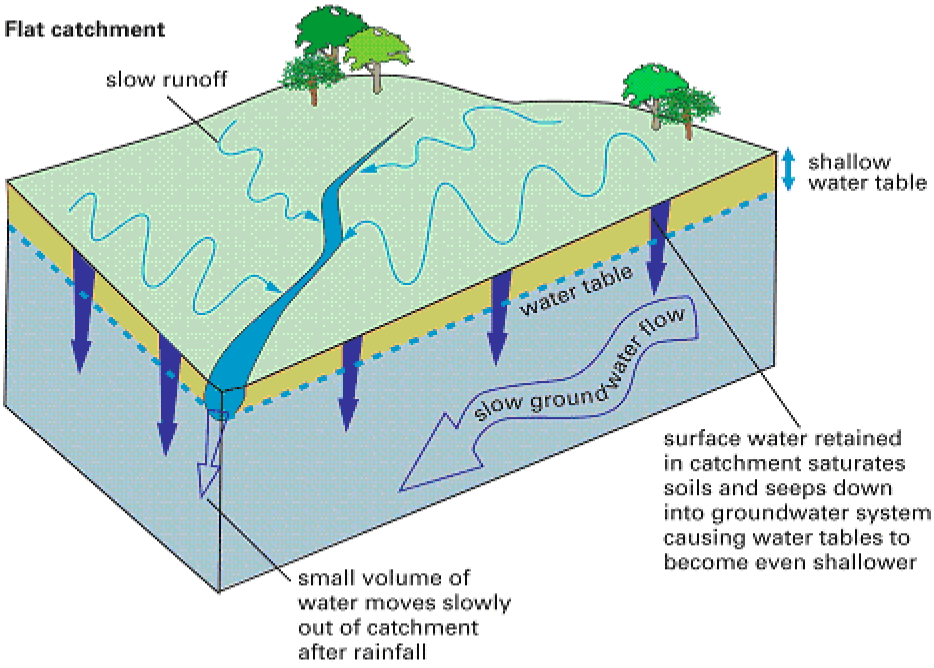


Figure 5: Catchment with shallow gradient, slow water drainage, water accumulation and groundwater rise.

Size of catchment outlet - A narrowing of the width (Figure 6) or a reduction in basement depth at the catchment throat (Figure 7) are common restrictions to surface water and groundwater outflow. The Murray-Darling Basin is a good example of a catchment with a very large area compared with the size of its outlet.

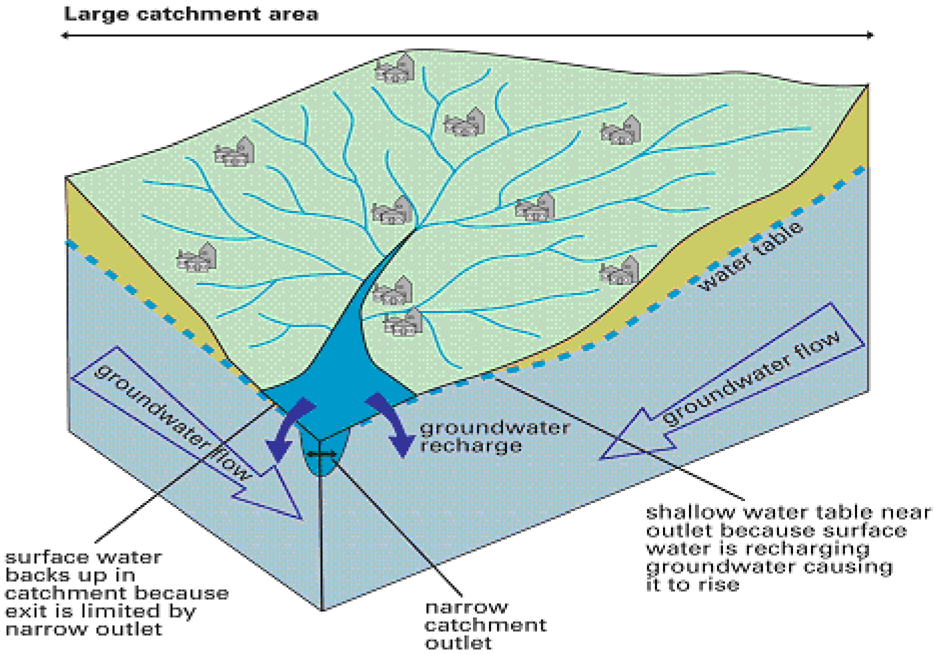


Figure 6: Narrow catchment mouth relative to area of catchment.

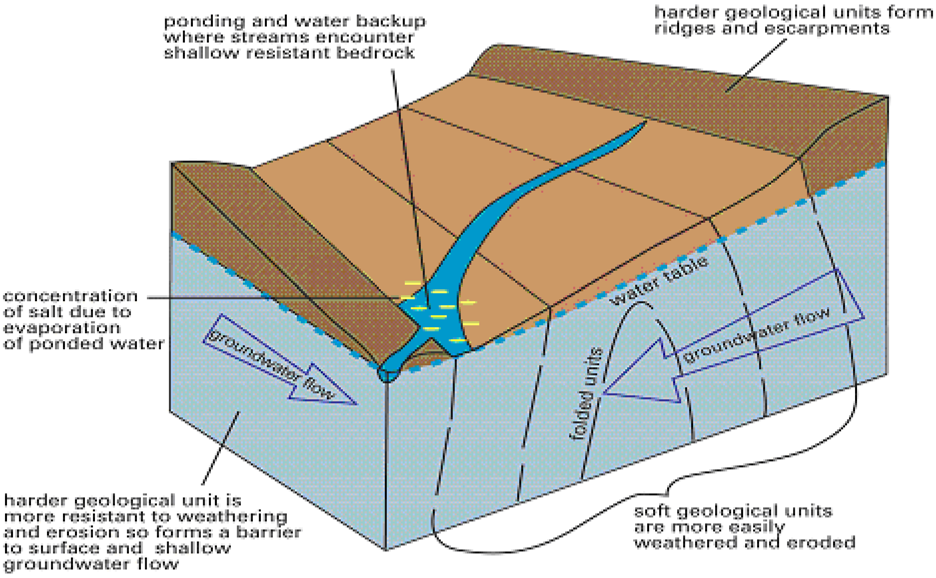


Figure 7: Reduction in basement depth at catchment mouth.

Absence of catchment outlet - Catchments with no surface water outlet are called 'internally draining' (Figure 8). Lake Eyre is an example of an internally draining catchment. All water entering an internally draining catchment must leave either by evaporation and transpiration or by drainage to the groundwater system. Evaporation in these catchments usually results in salt accumulation and the formation of salt pans (if dry) or salt lakes (if wet).

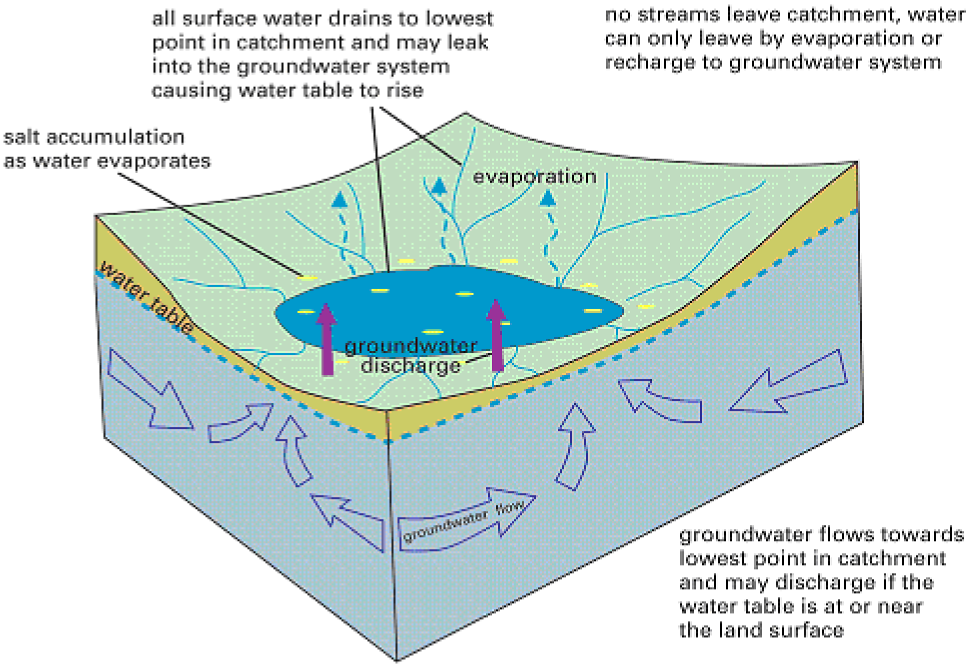


Figure 8: Internally draining catchment.

Changes in slope - The water table follows topographic contours but in a more diffuse way. Where the slope changes, the water table can come close to or intersect the land surface resulting in groundwater evaporation, seepage or springs (Figure 9 and Plate 3).

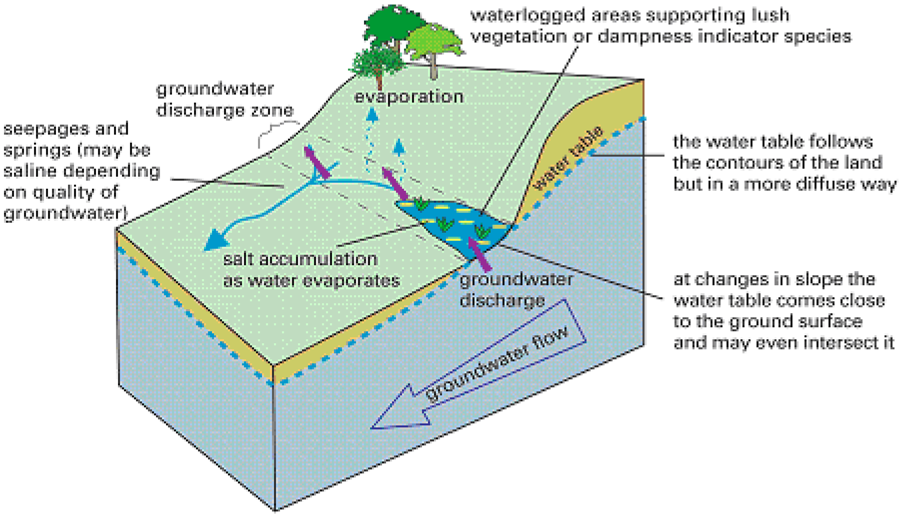


Figure 9: Change in slope causing groundwater discharge.

Plate 3: Lush vegetation supported by groundwater seepage at change in slope.

Hydrogeology

Groundwater systems can be grouped into local, intermediate and regional systems based on the length and depth of the groundwater flow path (Figure 10). These areas can then be further subdivided based on the similarity between landscapes and groundwater processes contributing to salinity and therefore by which salinity management options may be suitable for application. This enables limited resources to be used for the most effective monitoring and management of salinity.

Most areas seriously and consistently affected by dryland salinity have a combination of high groundwater levels (or pressures) in the local and the intermediate to regional groundwater systems.

Salinity management should focus on local groundwater systems where management will have the most effect.

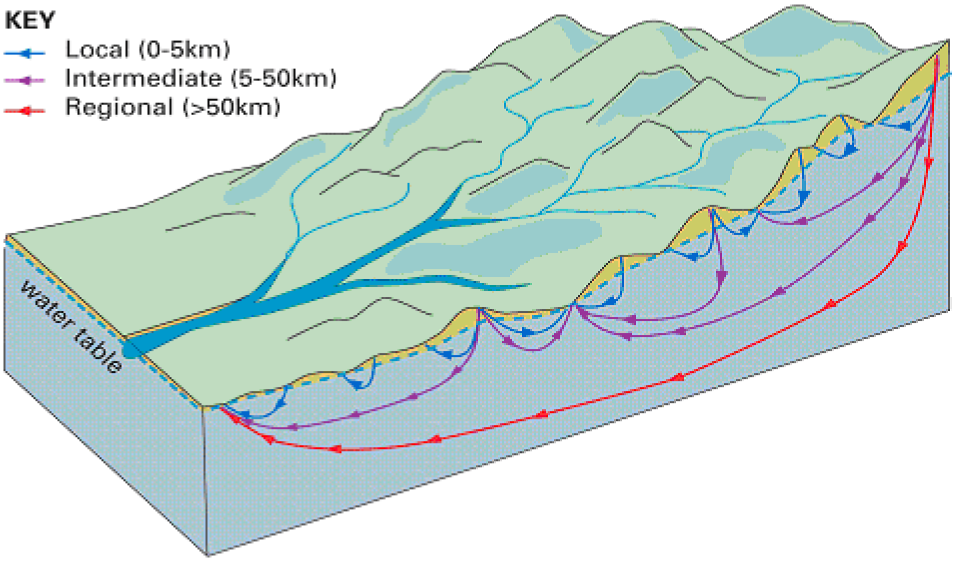


Figure 10: Local, intermediate and regional groundwater systems

Local groundwater systems

Dryland salinity often affects only a few properties over a relatively small area and is a local scale problem. Local groundwater systems determine where shallow groundwater will flow and discharge, and therefore the areas that will be affected by salinity. These are the systems to which salinity management practices should be directed to best mitigate and control shallow groundwater and hence loss of productive land and saline drainage to surface water systems.

The following characteristics are typical of local groundwater systems:

- develop in areas of pronounced topographic relief;
- short shallow groundwater flow paths (a few metres to less than five kilometres);
- contain relatively young groundwater (minutes to years old);
- groundwater flow directions are usually similar to those of surface water drainage;
- sit above intermediate to regional groundwater systems;
- recharge and discharge are close together (can be only metres apart);
- have a large recharge area relative to the size of the catchment;
- consists of mostly unconfined groundwater systems (some are semi-confined or confined);
- have generally rapid responses to changes in water inputs; and
- contain low and high storage capacity groundwater systems.

If intermediate and regional groundwater levels (or pressures) are high, then downward movement of water from overlying local groundwater systems cannot occur. This prevents shallow local systems from draining vertically or 'emptying'.

Intermediate and regional groundwater systems

Intermediate and regional groundwater systems extend over larger areas and much greater depths. Local salinity management will have minimal effect on these large systems which are driven by regional geology, elevation changes and longer-term climatic trends.

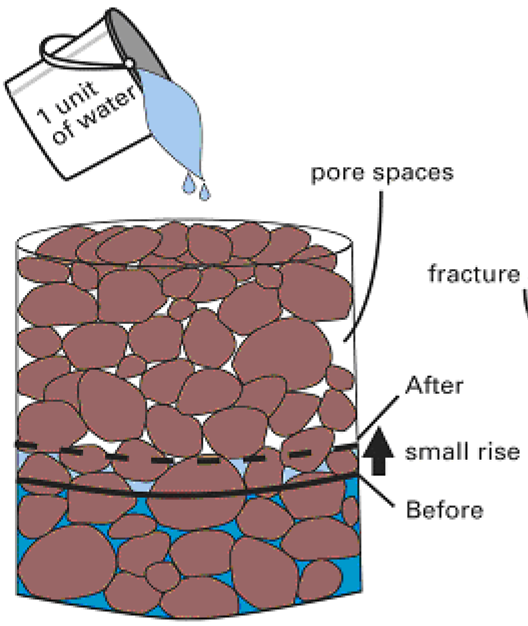
The following characteristics are typical of intermediate to regional systems:

- develop in areas with little or no topographic relief;
- groundwater flow directions are generally independent of local surface topography;
- longer deeper groundwater flow paths (five to hundreds of kilometres);
- contain many shallower local and intermediate groundwater systems;
- contain older groundwater, for example, Great Artesian Basin water is up to two million years old;
- recharge and discharge areas are further apart, perhaps hundreds of kilometres;
- have a small recharge area relative to the size of the whole system;
- are mostly confined groundwater systems;
- can take hundreds of years to respond to changes in water inputs;
- contain groundwater systems with storage that can expand and contract to accommodate water movement; and
- are more typical in large sedimentary basins, for example, Great Artesian Basin and Murray Basin.

Groundwater system characteristics - Groundwater systems can range from permeable to impermeable depending on the nature of the materials they are made up of. Some geological materials can store and transmit water more easily than others. This depends on the amount of free space (porosity) in the materials and how well connected the spaces are (permeability).

Geological units with large and well connected porosity, for example, sand and gravel, can accept greater amounts of water without showing significant groundwater level rise (Figure 11).

Geological units with small or poorly connected porosity, for example, most fractured rocks, have a limited capacity for groundwater storage and will show significant increases in groundwater levels with the addition of small amounts of water (Figure 12).



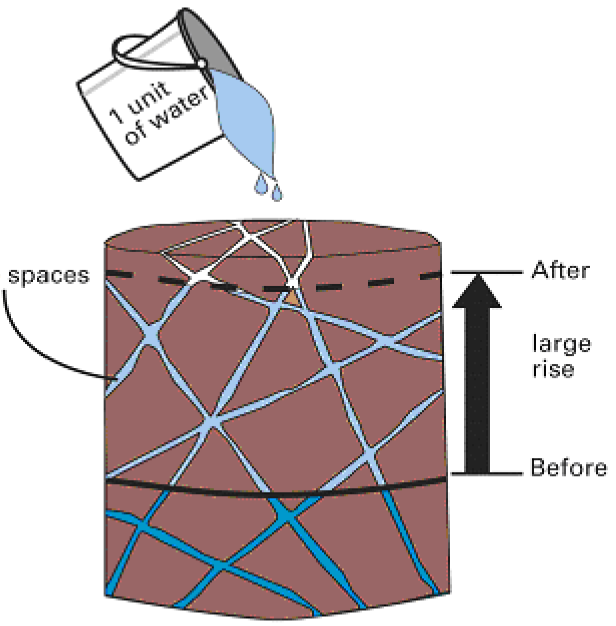


Figure 11:
Groundwater system with high storage capacity shows little change of water level on addition of water.

Figure 12:
Groundwater system with low storage capacity shows large change of water level on addition of water.

***Geology* -** When rock or soil materials with different permeability are overlying each other, or situated adjacent to each other, some of the moving groundwater can be forced to flow along the contact between the two materials rather than from one unit into another. Changes in geology along the groundwater flow path can cause a build up of groundwater and force discharge of the groundwater at the land surface (Plate 4). Figure 13 - Figure 16 represent these processes.

Plate 4: Rushes mid slope supported by groundwater discharge as soil texture changes downslope.

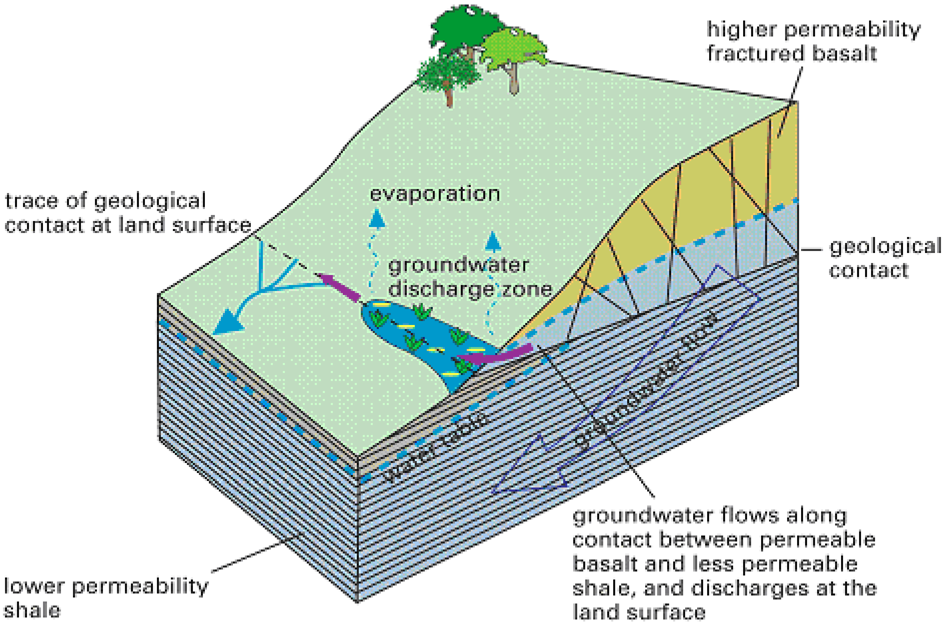


Figure 13: Groundwater forced to flow along contact between more permeable basalt and less permeable siltstone then discharges at the land surface.

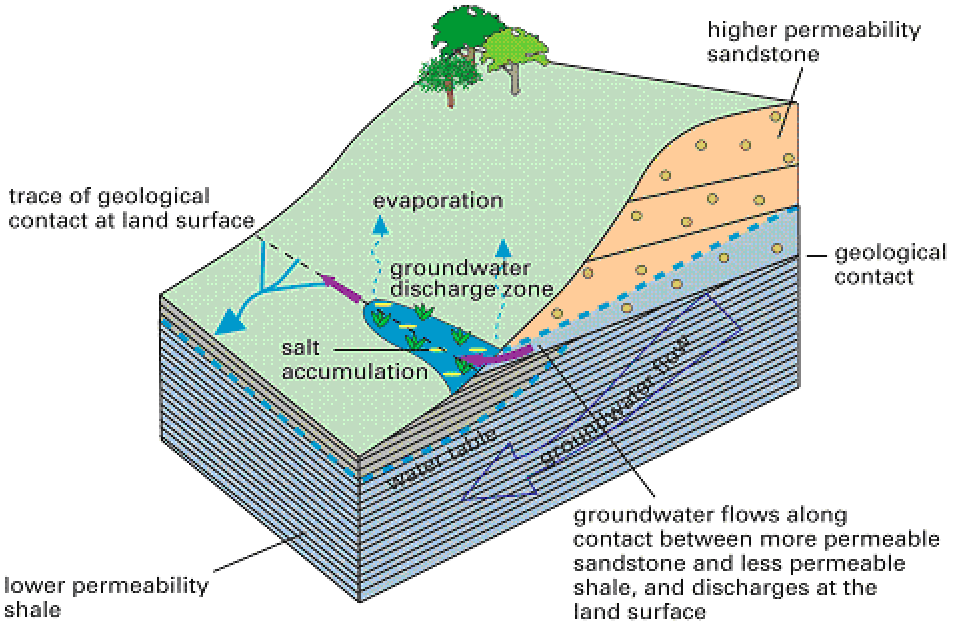


Figure 14: Groundwater forced to flow along contact between more permeable sandstone and less permeable siltstone then discharges at the land surface.

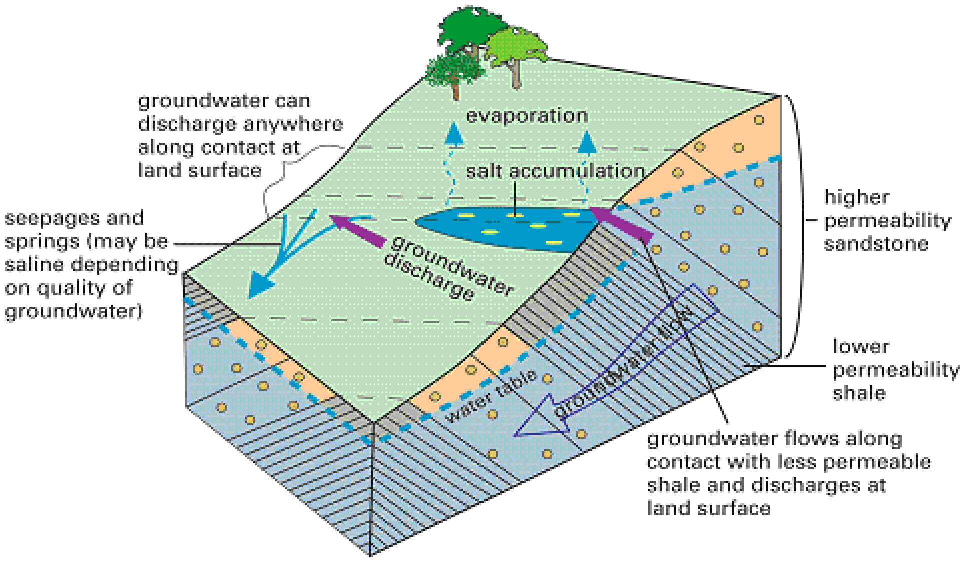


Figure 15: Groundwater forced upwards when it intersects less permeable unit.

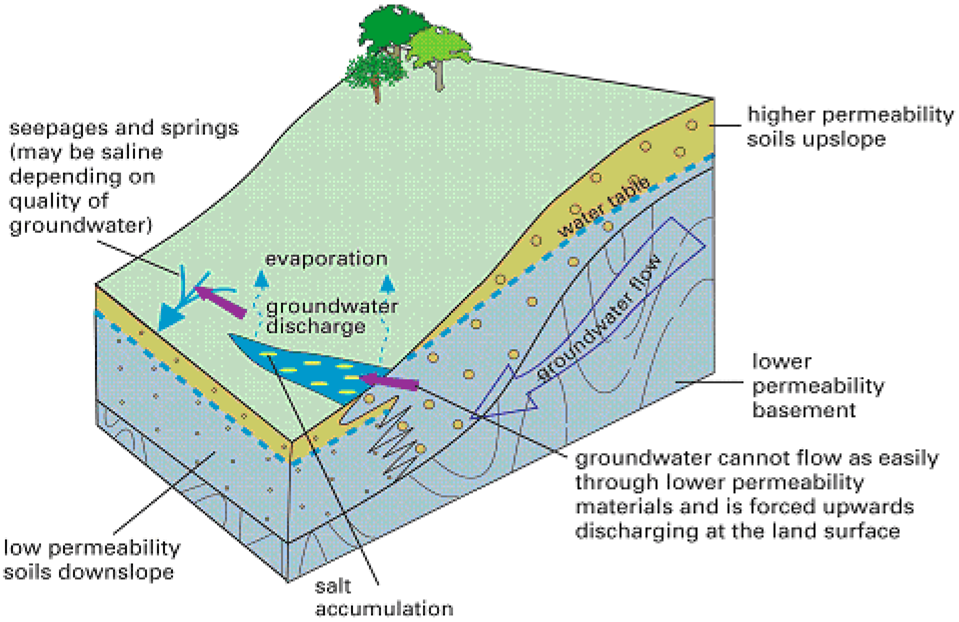


Figure 16: Water moving laterally downslope through soils is forced to ground surface where soils become finer grained and less permeable.

Geological structures - such as rock fractures and faults can control groundwater movement.

If these structures are permeable, they act as conduits to groundwater flow. If deeper groundwater is under pressure, these faults can allow groundwater to rise to the land surface (Figure 17).

If faults and fractures are filled with low permeability materials such as clay, they act as barriers to groundwater flow and can cause a build up and rise in level of shallow moving groundwater (Figure 18).

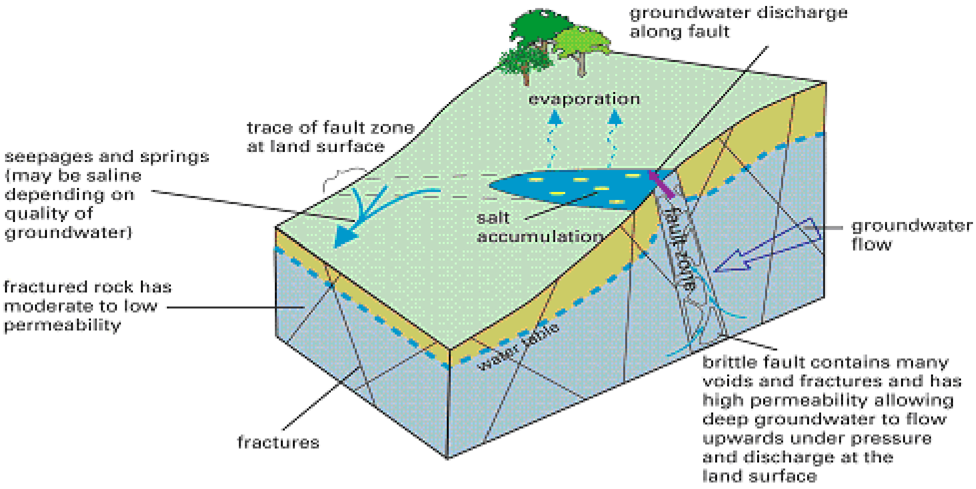


Figure 17: Fault acting as conduit for groundwater flow.

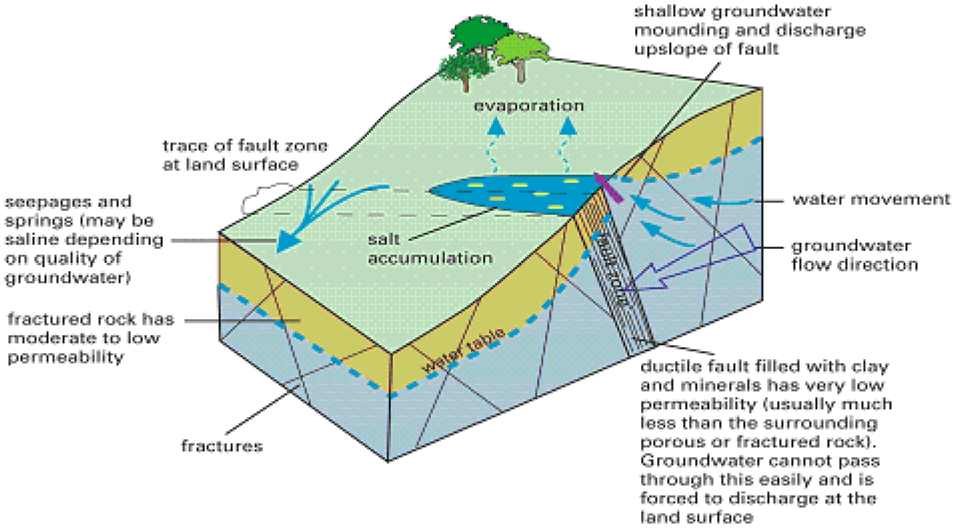


Figure 18: Fault acting as barrier to groundwater flow.

Soils

Soil plays a significant role in salinity management because it is the physical buffer between rainfall and groundwater recharge.

Healthy soils increase water retention and support active plant growth, using more soil water, thereby minimising the amount of water passing through the root zone to recharge groundwater.

In the absence of information about their long term impact, many of our past land management practices caused excessive loss of topsoil through erosion, compaction of topsoil and subsurface soil, soil structure decline, depletion of organic matter and increased acidity. These changes have resulted in degraded soils with a reduced water holding capacity.

The table below shows the potential loss in the water holding capacity of soils as a result of various types of soil degradation.

Table 1: Loss of soil water storage in degraded soils.

Source	**Sandy Loam/Loam (mm)**	**Sand/Clay (mm)**
Topsoil Loss	12.5	12.5
Soil Compaction (0-10 mm)	6.25	6.25
Soil Compaction (10-30 mm)	6.25	6.25
Soil Structure Decline	11.3	0.4
Organic Matter Loss	5.6	5.6
Estimated Total Water Loss	41.9	31.0
Water Loss - Topsoil Loss	29.4	18.5

(Source Packer and Lawrie 2004)

Table 1 shows that a loss of topsoil in all soils can lead to an estimated loss of 12.5 mm of water storage. A total of 41.9 mm of water storage is lost in both degraded sandy loam and loam soils, and 31 mm of water storage is lost in degraded sands and clay soils. This leads to a significant amount of water leaking past the root zone and into the groundwater system.

It is necessary to improve soil health to minimise the occurrence of dryland salinity. This can be achieved with land use systems that maintain complete groundcover for the majority of the year. This requires active and diverse plant growth, for example, crops and pastures, for as much of the year as possible. The use of organic wastes such as stubble and animal manures will also help to increase soil biological activity and improve soil organic matter levels. A gradual improvement in soil health will lead to better soil structure and water holding capacity, enabling growth of additional and healthier plants.

The effects of land use

Farming systems - Factors that contribute to rising groundwater levels are listed below.

- Clearing native vegetation - native plants are highly effective water users. Their removal is the single most important land use change contributing to salinity (Plate 5).

Plate 5: Vegetation clearing.

Growing annual crops and pastures - the shallow roots of these plants are unable to use water deep in the soil in the same way as native vegetation. They also only grow for part of the year, further reducing their water use (Plate 6).

Plate 6: Contrast in land use between native vegetation and European-style agriculture.

Overgrazing - reducing the leaf area of a plant reduces its ability to use water. This also limits root biomass for water uptake and soil organic matter improvement (Plate 7).

Plate 7: Overgrazing.

- Sowing late - if a paddock is lying idle through autumn and early winter, soil water accumulates due to little or no transpiration. This will increase the likelihood of recharge occurring when the soil profile is full.

- Long fallows - the aim of a fallow is to store the maximum amount of soil water. Often the soil is full prior to a crop being sown. Additional rainfall on the fallow area then results in recharge of the groundwater system (Plate 8).

Plate 8: Poor land management practices - long fallowing and soil compaction.

- Poor crop and pasture management - if disease and lack of fertiliser or any other factor limits growth, water use is restricted.
- Poor surface drainage - water lying on the landscape inhibits plant growth and water use and inevitably leaks through to the groundwater system.
- Decline in soil structure and health - the loss of topsoil, organic matter, soil structure and nutrients leads to a decline in vegetation health, limiting water use. A decline in the water holding capacity of soil also leads to an increase in groundwater recharge.

How to address these effects of farming systems

In some climates it is unlikely, and undesirable, that all groundwater recharge and consequent discharge will be controlled through better farming practices. However, excessive changes to the water balance can be limited by:

- ensuring a high percentage of groundcover throughout the year;
- increasing the amount of perennial species in the landscape;
- ensuring soil health is maximised physically, chemically and biologically (Plate 9 and Plate 10);
- increasing soil organic matter;
- adopting cropping and grazing systems to maximise plant growth;
- sowing crops early;
- using opportunity cropping in preference to fallowing;
- increasing perennial species in pasture systems (Plate 11); and
- tree planting that is complementary to agricultural productivity.

Plate 9: Good stubble retention - the use of organic wastes such as stubble and animal manures increase soil biological activity and improve organic matter levels.

Plate 10: Healthy soils supporting actively growing crop that uses soil moisture minimising leakage.

Plate 1:1 Healthy native perennial pasture.

Artificial restrictions to water flow **-** Structures such as roads and dams constructed across drainage lines can create barriers to surface water flow. Compacted ground below these structures limits shallow lateral groundwater movement. This causes water to accumulate and groundwater levels to rise on the up-gradient side of the structure (Figure 19 and Plate 12). Surface water dams and channels also contribute to salinity by retaining water in the catchment. This can leak into the groundwater system causing groundwater levels to rise (Figure 20 and Plate 13).

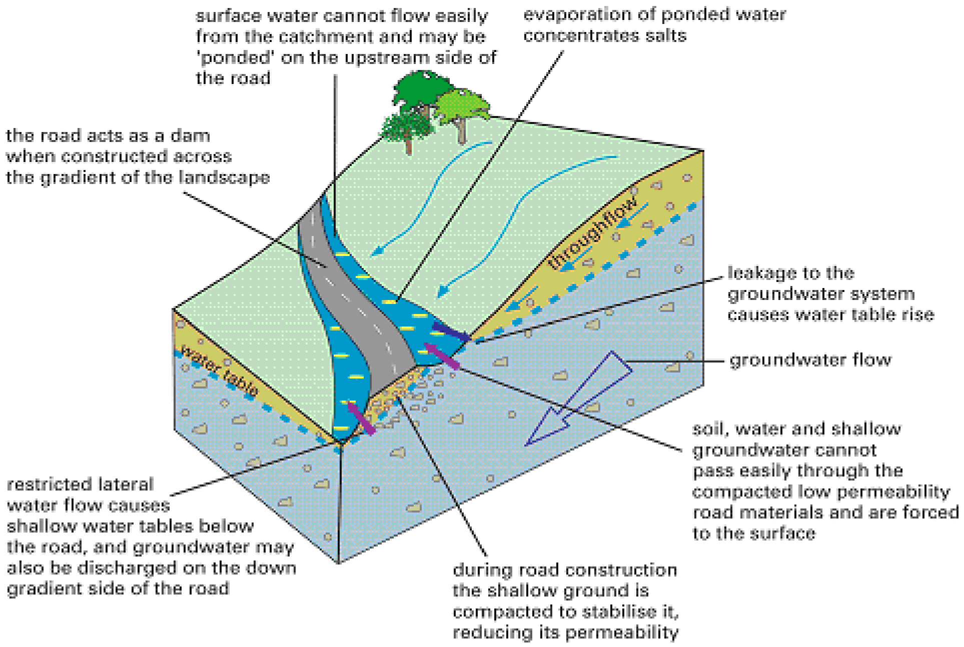


Figure 19: Road across drainage line limits water flow causing upgradient backup, local groundwater level rise, waterlogging, and salinisation.

Plate 12: Road restricting surface and shallow groundwater flow causes salinisation on upslope side of road.

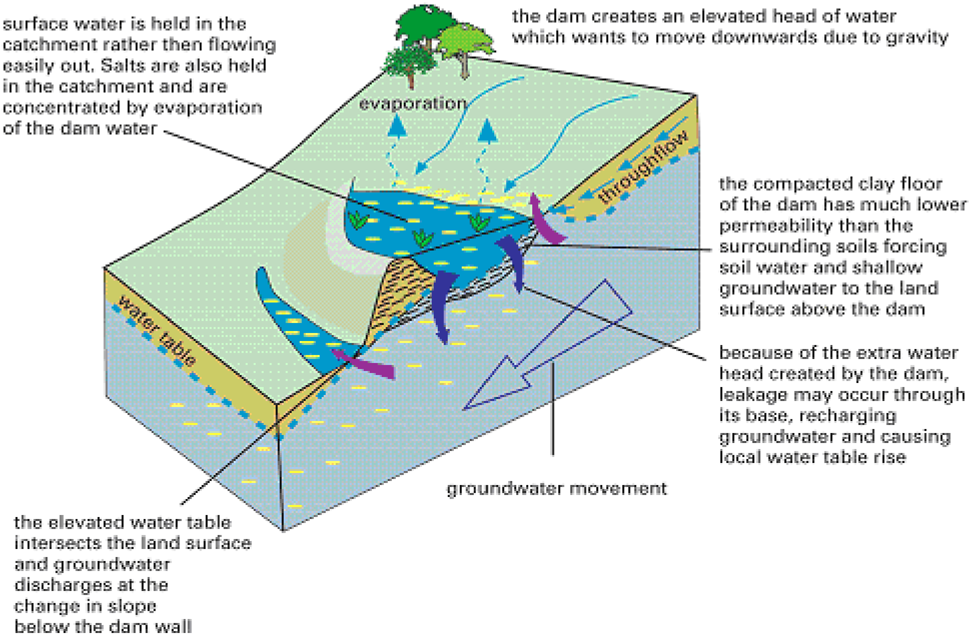


Figure 20: Dam impedes surface water and shallow groundwater flow, leakage results in local groundwater level rise, waterlogging and salinisation.

Plate 13: Leaking dam supporting vegetation growth downslope in drainage line.

4. Sources of salt

Many types of salt cause dryland salinity. They include sodium, calcium, magnesium, potassium, chloride, sulphate, bicarbonate and carbonate ions. Salt in the landscape is derived from the processes of weathering, deposition by rain, aeolian deposition and release of connate salt, as described below. The sources, quantity and composition of these salts vary markedly between areas. The management of saline sites varies depending on the types of salt present and their effects.

Weathering

Weathering processes break down the minerals in rocks and release soluble ions that combine to form salts. The type of ions released depends on the type of rock being weathered. Weathering can provide a steady contribution of mineral salts to the groundwater system, but is not the source of large quantities of salt.

The geochemical processes involved in weathering reactions are based upon the efficient removal of the weathering products from the reaction site. For significant weathering to occur, it must be associated with a continual flow of new water from recharge. If a flow of water is occurring through the groundwater system then salt will not be concentrated. An exception to this general rule is if the rock contains connate salt (see below).

Rain water

Airborne salts are contained in pollution, smoke and ocean spray. These salts are dissolved in atmospheric moisture and are deposited on the land during rainfall.

Rainwater generally contains 10 - 30 mg/L of salt. For rainfall of 500 mm per year, this works out to be 150 kg of salt per hectare per year (150 kg/ha/yr). The majority of this is washed directly into surface water systems.

In areas adjacent to the coast, substantial quantities of salt are received in rainfall, for example, at Mount Gambier rainfall contains approximately 25 mg/L of salt, which equates to 175 kg of salt per hectare deposited each year (Blackburn & McLeod 1983).

Ocean salt is also carried inland and deposited by rainfall, however salt concentration decreases with distance from the coast. At Wellington in the Central West of NSW, rainfall contains approximately 5.4 mg/L of dissolved salt, equating to a deposition of around 25 kg/ha/year (Blackburn & McLeod 1983).

Aeolian deposits

Strong westerly winds were generated in Australia during the dry windy glacial periods of the past two million years. These westerly winds carried large volumes of dust and salt from inland salt lakes, resulting in salt and dust being deposited across south-eastern Australia. Near Dubbo, one metre thick aeolian derived deposits contain 10,000 kg/ha of salt. Erosion of these deposits can release significant quantities of salt into waterways.

Connate salt

Some fine grained geological units, for example siltstone, that were deposited under marine conditions still contain significant amounts of salt that can be released to the groundwater system. For this reason, groundwater in these types of units is often of poor quality, especially where there has not been fracturing, uplifting and flushing.

5. The effects of dryland salinity

Dryland salinity is a form of land degradation that has significant long-term impacts. On-site impacts are associated with land and water salinisation and are clearly visible and quantifiable. Off-site impacts result from increased water salinisation and sediment load and are much less visible and quantifiable.

On-site impacts

The direct impacts of dryland salinity include:

- waterlogging and groundwater discharge that occurs as seepage, springs and baseflow to streams;
- build up of salt in the soil and associated toxicity;
- vegetation zoning towards increasingly salt and waterlogging tolerant species;
- decline in soil structure, formation of dispersive sodic soils, poor soil drainage and hard packing of soil surfaces;
- vegetation decline and death;
- decline and loss of productive land;
- erosion, loss of topsoil and formation of gullies;
- decreased surface water quality due to increased salt and sediment load from erosion of saline soils;
- decrease in local catchment gradient due to deposition of sediment, causing further retention of water in the catchment;
- increased salinity in local dams, lakes and streams due to surface washing of salts;
- increased salinity in local bores and wells due to accumulation and concentration of salts in shallow groundwater; and
- increased surface water salinity due to baseflow from shallow saline groundwater.

Off-site impacts

Increased surface and groundwater salinity and sediment load may have many off-site impacts including:

- decline in downstream biodiversity;
- deterioration in the health of riparian, aquatic and groundwater dependant ecosystems;
- decline in water quality used for human consumption, irrigation, stock and industry;
- degradation of downstream infrastructure such as buildings, roads and pipes.
- decline in water quality of connected groundwater systems; and
- changes to physical characteristics of waterways due to increased sedimentation and changed flow regimes.

Measurement of changes in salinity levels

Water salinity may be described and quantified in terms of salt load or salt concentration. The difference between these is explained below.

Salt concentration - is the amount of dissolved salts in a given volume of water. It is usually expressed in units as milligrams per litre (mg/L) of total dissolved salts (TDS). However, the most convenient method of estimating the salinity concentration in water is by electrical conductivity (EC). This is because dissolved salts conduct an electrical current in proportion to the amount of salt in the water.

Electrical conductivity is measured in Siemens, and is commonly expressed as deci-Siemens per metre (dS/m) or micro-Siemens per centimetre (µS/cm). These are referred to as electrical conductivity units or EC units.

To convert 1 dS/m (1000 µS/cm) to mg/L, a conversion factor of 0.64 generally applies (Table 2). The factor varies for very high salinity water or water with unusual chemical composition (see publication entitled "Dryland Salinity - Identifying Saline Sites" in this series for more on EC measurements).

Table 2: A guide to commonly used units for recording salinity measurements

1 =	1000 =	640*
deci-Siemens per metre (dS/m) or milli-Siemens per centimetre (mS/cm)	micro-Siemens per centimetre (µS/cm) or micromhos/centimetre (mhos/cm)	parts per million (ppm) or milligrams per litre (mg/L) or Total Dissolved Solids (TDS)

* Note: The conversion factor for ppm varies depending on the salts present. The variation at 1 dS/m can be from 400 - 970ppm. Due to the salts commonly present in soils, especially on saline areas, an accepted average conversion value is 640ppm.

Salt load - is the amount of dissolved salts in water carried past a designated point over a specified period of time.

Salt load is usually expressed as tonnes per day or tonnes per year. This value is strongly influenced by the volume of water flow (refer to Plate 14 and 15). For example, a river with a low salt concentration may still carry a large salt load because it has a high flow volume, so the net amount of salt transported is large.

Plate 14: Spicers Creek - Low flow, high EC (4354 µS/cm), low salt load (34 t/yr).

Plate 15: Macquarie River in flood - High flow, low EC (235 µS/cm), high salt load (303,293 t/yr).

6. Assessing salinity hazard and salinity risk

Investigation and monitoring of the factors contributing to dryland salinity allows the relative salinity hazard and salinity risk for a landscape to be determined. Salinity hazard and salinity risk are measures of the propensity of a landscape's biophysical characteristics, combined with its management, to express salinity.

Salinity hazard - is the extent to which natural physical characteristics, excluding land cover, predispose a landscape to salinisation. It is determined by a number of relatively stable long-term conditions that affect salinity processes. These include:

- climate (long-term average rainfall and evaporation);

- topography;
- catchment shape;
- groundwater system properties (for example, storage capacity, groundwater levels and groundwater salinity);
- geology;
- geomorphology;
- drainage or surface flow characteristics;
- regolith (thickness, type);
- soil attributes; and
- salt stores in the unsaturated zone.

The natural physical characteristics of a landscape change only slowly over time. Therefore the salinity hazard of a particular landscape is considered to be relatively constant within the usual timeframes for human intervention.

Salinity risk

Salinity risk is the likelihood of the salinity hazard being realised. It is determined by overlaying salinity hazard with conditions affecting salinity processes that can change over time. This provides a good indication of whether salinisation will occur, and the potential location, severity and extent that might be expected.

Salinity risk factors include:

- short-term extreme climatic events;
- land use;
- condition of vegetation; and
- condition of soil.

Salinity mitigation efforts should be directed towards changes in land use and management that will alter the salinity risk for that landscape at that particular time.

The relationship between salinity hazard and salinity risk

Some areas in a landscape have a naturally high salinity hazard due to existing conditions such as high salt stores. However, whether salinity will occur depends on the salinity risk. The actual risk of salinisation may be low even where there is a high hazard, because some conditions affecting the potential for salinity to be expressed, such as land use, can be managed effectively.

Assessing the relative salinity hazard and risk is useful for guiding selection and timing of interventions in a particular landscape. It also allows different areas to be compared and ranked for priority management.

Mitigating salinity risk

Action taken to prevent or mitigate salinity risk should be both effective and feasible.

Feasibility of implementing effective mitigation actions depends on:

- biophysical possibility (certain land management practices have specific biophysical requirements to be successful);
- social acceptability (certain land management practices may be socially unacceptable to the land managers or community);
- availability of skills to implement the change;
- economic viability (certain land management practices are beyond the financial capabilities of the land managers); and

- regulatory/legislative impetus.

Further information

This booklet provides an introduction to dryland salinity, processes and factors contributing to its development the impacts and a guide to assessing salinity hazard and risk. Readers are encouraged to seek further information on dryland salinity and it's management from the Catchment Management Authority, the Department of Primary Industries or the Department of Infrastructure, Planning and Natural Resources.

Glossary

Aeolian	Material transported and deposited by wind, eg materials forming dunes.
Artesian	Where groundwater is under sufficient pressure to rise above the ground surface.
Baseflow	Groundwater that discharges into surface water systems such as streams and lakes.
Capillary Rise	The upward movement of water caused by the molecular attraction between soil particles and water. This occurs when dry soil acts as a sponge drawing groundwater towards the surface.
Confined Groundwater System	A groundwater system that is isolated from atmospheric pressure by a layer of impermeable material and where the upper pressure level is represented by the piezometric surface.
Discharge	The loss of water from a groundwater system, eg can occur through evaporation, pumping, seepage, springs and baseflow to rivers and lakes.
Discharge Area	An area where groundwater is discharged at the ground surface.
Dryland Salinity	Occurs in non-irrigated areas. It includes both naturally occurring salinity and salinity that results from increased recharge under dryland farming systems. Dryland salinity may also be caused by soil erosion, which can result in the exposure of saline sub-soils.
Groundwater Equilibrium	A condition in which the amount of recharge to a groundwater system equals the amount of natural discharge.
Evaporation	The process by which water passes from liquid to vapour and enters the atmosphere.
Evapotranspiration	The sum of evaporation and transpiration.
Fault	A break in rock in which the adjacent rock surfaces are displaced parallel to the plane of movement.
Fracture	A break in rock in which the adjacent rock surfaces are not displaced parallel to the plane of movement.
Fractured Rocks	Rocks in which spaces are created by fractures, joints and partings. These provide groundwater storage and flow paths.
Groundwater	Water that occurs beneath the ground surface in the saturated zone.
Hydrogeology	The science that deals with sub-surface waters, including the geology of water-bearing rocks, the chemistry, physics and movement of groundwater, and the laws governing groundwater movement.
Recharge	The addition of water to a groundwater system.

Recharge Area	An area on the ground surface where surface water from rain, irrigation or water bodies infiltrates the soil adding water to the groundwater system.
Saturated Zone	Ground materials in which all spaces are filled with water.
Soil Water	Water contained in the unsaturated zone that is bound to soil particles above the saturated zone.
Throughflow (= Lateral Flow)	Water that moves laterally in the unsaturated zone.
Transpiration	The process by which plants give off water vapour through their leaves.
Unconfined Goundwater System	A groundwater system usually near the ground surface that is in connection with atmospheric pressure and where the upper level is represented by the water table.
Unsaturated Zone	Ground materials in which spaces are empty or partially filled with water.
Water Table	The upper surface of groundwater (at atmospheric pressure) below which the layers of rock, sand and gravel are saturated with water.

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