Chapter 11 — Water quality

Water quality needs to be evaluated from the perspective of its intended use. 'Suitability' criteria for salt composition and concentration for domestic use, for example, will be quite different from those for stock watering, irrigation and industrial uses.

Water quality guidelines for a variety of uses in Australia have been proposed by the Australia and New Zealand Environment and Conservation Council (ANZECC 1992), based on earlier guidelines. The 1992 guidelines are currently under review.

Domestic use

Guidelines for water quality suitable for human domestic use have been developed by ANZECC (1992) and others (such as NHMRC).

Many aspects of water composition and quality determine whether a water is suitable for human consumption.

As an approximate guide for salinity only, total salinity in drinking water should be less than 1 000 mg/L (approximately EC 1.6 dS/m), based on taste considerations.

To determine whether a water is suitable for human domestic use, submit water samples to local health authorities for a complete analysis.

Stock watering

Highly saline waters can cause physiological disturbances in stock, such as gastrointestinal distress, wasting and sometimes death. Common conditions causing physiological stress, such as reproduction, lactation or rapid growth, place animals particularly at risk. In some situations, stock will refuse to drink saline water or will drink less than usual. Stock may bypass saline water sources, or may drink only enough to satisfy their salt needs. In other situations, thirsty animals may drink excessively and suffer ill effects.

The recommended guidelines presented in this section are largely determined by field observation and not from rigorous experimentation (ANZECC 1992; Gill 1986a). These guidelines consider the suitability of waters for stock from the perspective of salinity only. Other features of waters which would require investigation include possible contaminants (heavy metals, pesticides or herbicides) and pathogenic organisms. (Guidelines for other water quality factors are provided in ANZECC 1992 and Gill 1986b.)

Interpretation and classification

A number of factors affect an animal's ability to tolerate saline water (without undue harm to health), and these should be taken into consideration when applying any guidelines (ANZECC 1992; Gill 1986b; Winks 1963). The presence of high concentrations of certain compounds in drinking water may necessitate adjustments to diet.

The ability of stock to tolerate saline waters depends on the levels of specific ions and salts as well as total salinity.

Some animal species can tolerate salinity better than others. In approximately decreasing order of salt tolerance are sheep, horses, cattle, pigs and poultry. Older animals appear to be able to tolerate higher salinity levels than younger animals. Animals which are lactating or weak require better quality water.

If stock are introduced gradually to marginally saline water, they can often adjust to the salinity levels. However, stock given saline water to which they have not become accustomed can suffer ill effects or refuse to drink. Stock should be able to tolerate increasing salinity levels during dry periods because they become accustomed to the changing levels over time. However, stock are less tolerant of saline water during hot, dry periods. It is during these times that stock need to consume more water, and that water supplies often become more saline due to evaporative concentration.

Stock on green pastures or silage can tolerate higher levels of salinity in drinking water because of the (usually) non-saline water content of the pasture. However, pastures grown on saline soils generally have higher salt levels and this also needs to be considered when determining water requirements. If stock are on prepared feed, the salt content of the feed should be assessed and possibly reduced to compensate for salt levels in water. Higher salinity levels can be tolerated if green feed is available near to the water supply, and stock do not have to travel some distance to obtain water.

The total salinity levels presented in Tables 34 and 35 are considered acceptable, provided the concentration of specific ions or salts does not exceed the limits in Tables 34 and 35, especially if salinity concentration exceeds about 3.5 dS/m (ANZECC 1992). It is advisable to measure at least magnesium concentration in addition to total salinity when assessing waters for stock.

Table 34. Guidelines for upper limits of salinity concentration in waters for stock (after Hart 1974, in ANZECC 1992). See also Table 35.

Stock	Desirable maximum concentration for healthy growth		Maximum concentration at which good condition might be expected		Maximum concentration that may be safe for limited periods	
	(dS/m)	(TDS mg/L)	(dS/m)	(TDS mg/L)	(dS/m)	(TDS mg/L)
Sheep	10.0	6 000	22.0	13 000	*	*
Beef cattle	6.7	4 000	8.3	5 000	16.7	10 000
Dairy cattle	5.0	3 000	6.7	4 000	10.0	6 000
Horses	6.7	4 000	10.0	6 000	11.7	7 000
Pigs	3.3	2 000	5.0	3 000	6.7	4 000
Poultry	3.3	2 000	5.0	3 000	6.7	4 000

Note: *Depends on type of feed. Berkman (1989) suggests an upper limit of 14 000 TDS mg/L (23.3 dS/m).

Table 35. Alternative guidelines for upper limits of salinity concentration in waters for stock (Source: Gill 1986b).

Stock	Desirable maximum concentration		Upper level for limited periods	
	(dS/m)	(TDS mg/L)	(dS/m)	(TDS mg/L)
Sheep	15.0	10 000	21.0	14 000
Beef cattle	13.5	9 000	15.0	10 000
Dairy cattle	10.5	7 000	15.0	10 000
Horses	7.5	5 000	9.0	6 000
Pigs	7.5	5 000	10.5	7 000
Poultry	4.5	3 000	6.0	4 000

Some landholders may find that their stock animals thrive on water that is more saline than recommended. Others may find their stock can only tolerate lower levels. This is to be expected, and will result from the interaction of factors mentioned earlier.

If most factors are favourable (climate, feed, stock in good condition), there should be few problems using stock water with salinity levels close to the recommended limits. Unfortunately, it is usually when climatic conditions are unfavourable that marginal quality water supplies will be called on. It is advisable to manage the introduction of more saline water by mixing good and marginal quality waters or by conserving some good quality water and alternating its supply with marginal quality water (Gill 1986b). Drinking troughs also need to be flushed out regularly to remove salt concentrated by evaporation.

Specific ion concentrations

In addition to total salinity concentration, levels of specific ions can be harmful to stock.

Calcium

ANZECC (1992) recommends that if calcium is the dominant ion, the concentration of total calcium in stock water should not exceed 1 000 mg/L (Table 36, page 81). If the water contains high concentrations of magnesium and sodium, the acceptable level of calcium should be adjusted downwards.

Nitrate

High levels of nitrate are not usually found in natural waters, except in water bodies containing decaying organic matter. Waters containing seepage from highly fertile soils, areas fertilised with large quantities of nitrogen fertiliser, or effluent from intensive rural industries may also have high nitrate concentrations (Gill 1986b).

Gill (1986b) held that animals can probably tolerate considerably greater levels of nitrate than the quantity shown in Table 36. However, when nitrate is converted to nitrite after ingestion, the nitrite combines with haemoglobin, reducing the oxygen-carrying capacity of the blood. To reduce the risk, the water should be kept well aerated and free from contamination.

Table 36. Recommended upper limits for specific ions, salts or trace elements in waters for stock (adapted from ANZECC 1992, Gill 1986a, and Gill 1986b).

Specific ion or salt	Maximum concentration (mg/L) (all stock unless otherwise specified)			
	ANZECC 1992		Gill (1986b)	
Major ions and nutrients				
Calcium		1 000		
Nitrate	sheep	60	pigs, poultry	100
	cattle	40	other stock	250
	horses	30		
	other stock	30		
Nitrite		10	n/a	10
Sulfate		1 000		1 000
Sodium bicarbonate		n/a		1 000
Trace elements				
Boron		5.0		n/a
Fluorides		2.0		2.0
Magnesium	Refer to Table 37 for stock tolerances of various salinity levels with magnesium concentrations less than 600 mg/L	600	sheep	500
			poultry	250
			young pigs and other stock	400

Nitrite

Elevated levels of nitrite are not usually found in natural waters, so they are not routinely tested for when water samples are sent for analysis. If, for some reason, the person supplying a water sample for testing suspects that nitrite may be a source of concern, this should be specified when samples are forwarded to the laboratory.

Sulfate

High sulfate levels can cause scouring and general loss of condition (ANZECC 1992, Gill 1986b). In Queensland, sulfate levels alone are rarely a problem as high sulfate concentrations usually occur only in waters with high general salinity.

Sodium bicarbonate

Sodium bicarbonate in drinking water can cause sheep to bloat, particularly if the animals are under stress and not accustomed to the water (Chippendale 1971, in Gill 1986a). The quantity shown for sodium bicarbonate in Table 36 applies to stock that are not accustomed to sodium bicarbonate in water; stock may adjust to higher levels of sodium bicarbonate if introduced to the water gradually.

Boron

Boron may be present in groundwater, but groundwater concentrations are usually less than the recommended maximum concentration. Excessive concentrations of boron can cause decreased appetite and loss of weight (Green & Weeth 1977, in ANZECC 1992).

Fluoride

If waters with fluoride concentrations greater than the recommended level are used exclusively for young stock for the first three years of life, the fluoride has been found to weaken their teeth (Gill 1986b). High fluoride levels can cause bone lesions in older animals. High fluoride levels are normally found only in artesian and sub-artesian bores tapping the Great Artesian Basin (Gill 1986b). Such waters often contain elevated sodium bicarbonate concentrations as well.

If feed contains fluoride, the acceptable limit for fluoride in drinking water should be reduced to 1.0 mg/L (ANZECC 1992).

Magnesium

High magnesium levels can cause scouring. Magnesium levels are a particular problem with many Queensland waters. In some cases, stock have been reported as thriving on levels in excess of those recommended by Gill (1986b, Table 36), indicating either that stock may be able to adjust to higher magnesium concentrations (Gill 1986b) or that magnesium tolerance depends to a degree on total salinity (ANZECC 1992, Table 37).

Irrigation

The increasing demand placed on water supplies throughout Australia will mean that irrigated agriculture faces the challenge of using less and/or poorer quality water to maintain production. An increased reliance on groundwaters and reuse of surface waters means that water quality will be ‘poorer’ than surface water or rainwater. The salinity and sodicity levels of these waters will be higher than surface water supplies and irrigation management will need to be modified to enable sustainable use of these poorer quality waters.

Irrigation water quality criteria depend on soil properties, climate (rainfall in particular), plant species and management practices. Since these factors interact to define acceptable quality in a given situation, water composition alone provides only a rough guide under average conditions.

A number of irrigation water assessment guidelines have been developed over the years. Schemes which have been in common use in Australia are listed in Table 38, along with their rationales. Shaw et al. (1987) provide a more detailed discussion of some significant problems with the extrapolation of these guidelines to Queensland conditions. The main limitations of these schemes are:

- local region derivation for soil and climatic conditions not readily transferable to Queensland conditions
- conditions of use not defined
- too conservative
- most of the sodicity evaluations incorrect
- salinity classes cannot be readily related to plant salt response.

Table 37. Suitability of water as livestock drinking water with magnesium < 600 mg/L and various concentrations of salinity (EC dS/m).

Salinity criteria with magnesium < 600 mg/L		Recommendations
EC (dS/m)	TDS (mg/L)	
< 7.8	< 5 000	
7.8–15.6	5 000–10 000	Generally unsuitable for lambs, calves and weaners. Caution needed with lactating stock if unaccustomed. Suitable for dry, mature sheep and cattle.
> 15.6	> 10 000	Suitable for dry, mature sheep. Caution needed with cattle if unaccustomed.

Note: Magnesium levels > 600 mg/L generally unsuitable for all stock. (Flinn 1984 in ANZECC 1992).

Irrigation water salinity and sodicity classification

Irrigation salinity can develop from watertable salting, or from the use of poor quality irrigation water. Salting from the use of poor quality irrigation water occurs in irrigated soils where there is insufficient leaching to remove salts from the root zone, resulting in increased salinity levels as more salt is added with each application of irrigation water. The extent of this problem is difficult to assess and can be partly controlled by choice of salt-tolerant crops and water management strategies. Where supplementary irrigation (irrigation at levels less than annual rainfall) is the norm, salinity is of less concern than sodicity because salt levels can be reduced dramatically by wet season rainfall.

Inherent in the philosophy of many of the water quality guidelines for irrigation is the control of soil salinity by leaching with increasing levels of water application. This is satisfactory for permeable soils, but for slowly permeable soils (1–10 mm/d for a range of Queensland soils), leaching is dominantly controlled by soil properties rather than irrigation water management. For clay soils, leaching is strongly influenced by the salinity and sodicity of the irrigation water. Thus, threshold values are needed which define the boundary between stable permeability and decreasing permeability for combinations of irrigation water salinity (EC) and SAR.

Decreasing permeability is generally the result of increased soil surface dispersion due to insufficient salt content within the surface layers to flocculate the soil. This problem is obvious with rainfall events after irrigation with sodic waters. In rainfall periods, the total salt content in the surface soil solution is lowered by leaching. The ESP will not be reduced as much because in a given volume of soil the number of exchangeable ions (that is, ions held on exchange sites on soil particles) is generally 50 to 500 times greater than the number of ions in the soil solution. Consequently, the number of calcium and magnesium ions available in the soil solution is much lower than the number needed to replace exchangeable sodium.

If EC becomes too low to counteract the effects of exchangeable sodium, clay swelling and dispersion occurs, resulting in reduced infiltration rates and soil permeability.

A relationship between EC_{se} and ESP was determined from an examination of the properties of subsoils of non-irrigated soils across a wide range of rainfall environments in Queensland (Shaw & Thorburn 1985a, Shaw 1996). This relationship reflects the natural equilibrium between EC and ESP that develops under a given rainfall, and can be used to establish guidelines for the permissible SAR of an irrigation water (Table 39). These guidelines were developed for a permissible SAR which should maintain surface soil stability under high leaching situations associated with heavy rainfall, due to the reasons highlighted previously in this section.

Table 38. Irrigation water quality guidelines in use in Australia.

Assessment scheme	Comment
USSL (1954), Hart (1974), VIRASC (1980), ANZECC (1992)	• Guidelines on salinity and SAR based on plant response. • SAR criteria based on amount of sodium added to the soil and not in agreement with current views of the influence of sodium on stability of the soil. • Salinity criteria are conservative and don't account for rainfall.
Rhoades (1983)	• Predicts salinity, sodicity and concentration of toxic solutes in the soil water within a simulated crop root zone under irrigation with a specified water composition and specified leaching fraction. • Evaluates effects of predicted salinity on crop yield and the effects of predicted surface soil sodicity on soil permeability. • Computer version WATSUIT uses an equilibrium chemistry model with options to consider the water composition amended with gypsum or sulfuric acid. The resultant predictions are then compared with the crop salt-tolerance data of Maas and Hoffman (1977) to determine crop suitability. • Appropriate where soil leaching fraction is known and can be varied with irrigation water management. • No account is taken of changes in soil leaching with increased electrolyte or sodicity under irrigation, which is particularly important for clay soils. • Model copes well with waters containing gypsum.
Cass & Sumner (1982)	• Based on earlier work of Cass (1980) incorporating soil and climatic factors in a water quality assessment method based on the model of Bernstein (1967) for slowly permeable soils. • Incorporates an empirical 'sodium stability model' to evaluate soil hydraulic conductivity reduction and aggregate stability with varying electrolyte and sodicity levels. • Crop yield is determined from the predicted soil solution composition related to the data of Maas and Hoffman (1977) through a yield index. • Difficulties with the model for Queensland are the requirement for a measured or estimated soil drainage flux, particularly for clay soils; model doesn't allow for increases in soil drainage flux with increased electrolyte concentration; the use of laboratory measured hydraulic conductivity on disturbed samples is not related to field processes in soils with macropores (Bouma 1983); and the significance of unsaturated flow in leaching in slowly permeable soils is probably higher than the low saturated hydraulic conductivity values would suggest.
Ayers & Westcot (1985)	• First published in 1976 with a revised version published in 1985. • Method for identifying potential infiltration problems due to SAR as modified by EC has been adapted from Rhoades (1977) and Oster and Schroer (1979). • Recommends use of an adjusted SAR concept as developed by Suarez (1981) which offers better insight into the change in calcium concentration in the soil water due to addition by dissolution of calcium from soil carbonates and silicates, or loss of calcium from soil water by precipitation as carbonates. • Water quality evaluated by salinity effect on water infiltration rate, toxicity and a group of miscellaneous problems (such as high nitrogen and high iron concentrations). • The need to incorporate rainfall into the guidelines is a limitation for application in Queensland.

Residual alkali

Residual alkali (RA) is another measurement often considered when determining the likely impact of water quality on soil properties. Residual alkali represents the excess of sodium bicarbonate and carbonate ions over calcium and magnesium ions in the water. These salts combine with calcium and magnesium in the soil solution, removing them by precipitation. This leaves an excess of Na^+ ions with a consequent increase in the ESP of the soil. The adjusted RNa approach of Suarez (1981) as recommended by Ayers and Westcot (1985) will correct for the effect of residual alkali on ESP. Residual alkali on its own is not a useful indicator of sodicity hazard as waters may have high SAR and little or no RA, for example when sodium chloride is the dominant salt.

Table 39. Guide to permissible SAR of irrigation water to maintain a stable soil surface following heavy rainfall periods.

Clay content (%)	Soil texture	Permissible irrigation water SAR* Clay mineralogy expressed as CCR (mole$_c$,kg)				
		< 0.35 non-cracking**	0.35–0.55 non-cracking	0.55–0.75 cracking**	0.75–0.95 strongly cracking	> 0.95 very strongly cracking
< 15	sand, sandy loam	> 20	> 20	> 20	> 20	> 20
15–24	loam, silty loam	20	11	10	10	8
25–34	clay loam	13	11	8	5	6
35–44	light clay	11	8	5	5	5
45–54	medium clay	10	5	5	5	5
55–64	medium–heavy clay	5	5	5	4	4
65–74	heavy clay	–	4	4	4	4
75–85	heavy clay	–	–	4	5	5

* Values calculated assuming surface soil EC equal to undisturbed soil in Lockyer Valley, modified from Shaw and Thorburn (1985a) at 2000 mm rainfall.

** Cracking or non-cracking applies only if clay content is greater than about 35%.

Plant response to saline irrigation water

When assessing water quality for irrigation, the recommended approach is to assess water quality parameters and soil properties. With this information, leaching fraction can be determined, from which soil root zone salinity and plant response can be determined (refer to ***Converting leaching fraction to root zone salinity*** page 36). Other factors such as climate, crop type and irrigation management are also important when making recommendations on water suitability.

The following criteria (Table 40) are proposed as general, broad guidelines for average conditions based on the plant salt-tolerance groupings of Maas and Hoffman (1977) and using an average of 15% leaching fraction without considering rainfall.

Table 40. Irrigation water quality criteria for salinity based on 90% yield of the plant groupings of Maas and Hoffman (1977), assuming 15% leaching fraction. (Details of the derivation of the criteria are provided in Shaw et al. 1987)

Irrigation water quality (assume LF = 0.15)		Water salinity rating	Plant salt-tolerance grouping
EC (dS/m)	Chloride (mg/L)		
< 0.65	< 220	very low	sensitive crops
0.65–1.3	220–440	low	moderately sensitive crops
1.3–2.9	440–800	medium	moderately tolerant crops
2.9–5.2	800–1500	high	tolerant crops
5.2–8.1	1500–2500	very high	very tolerant crops
> 8.1	> 2 500	extreme	generally too saline

One limitation of the general guidelines is the use of 15% leaching fraction to estimate plant response. Table 5 (page 23) highlights the range of leaching fraction values possible for various soils.

Soil sodicity response to irrigation

Sodium in waters and the soil solution is usually expressed as SAR because of its close relationship with the ESP of the soil. The proportions of Ca^{2+}, Mg^{2+} and Na^{+} on the soil exchange are not identical to the proportions in the soil solution because the divalent cations are preferentially adsorbed onto the clay exchange surfaces. ESP can be calculated from SAR using the relationship of USSL (1954):

$$ESP = \frac{100(-0.0126 + 0.01475\text{SAR})}{1 + (-0.0126 + 0.01475\text{SAR})} \quad \ldots\ldots\ldots\ldots\ 29$$

This equation has been found to provide practical predictions in many situations including Australian soils (Skene 1965).

The reverse equation for obtaining SAR from ESP based on the regression of the original USSL (1954) data is as follows:

$$SAR = 0.6906ESP^{1.128} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 30$$

$(R^2 = 0.888)$

This equation is valid for ESP values between 0 and 50. Details are given in ***Useful conversions and relationships*** (page 158).

Predicting changes in SAR

The SAR of a water provides an indication of the effect an irrigation water is likely to have on a soil. A number of factors influence the relationship between ESP and SAR. In particular, the proportion of bicarbonate and calcium ions can result in the precipitation of $CaCO_3$, removing Ca from the system. Also, with depth in the root zone, the soil solution is concentrated by root water extraction, resulting in precipitation of the less soluble salts. However, the partial pressure of CO_2 is higher in the root zone due to root activity, with the result that carbonate salts remain in solution.

Additionally, the amount of deep drainage (or leaching) has an important effect in changing the concentration of salts in the root zone. Prediction of leaching from soil properties as outlined in ***Relationship between salinity, sodicity and soil properties*** (following) provides the theoretical background to allow incorporation of salinity-sodicity relationships into prediction of the impact of sodium in irrigation waters. Relationships developed to predict changes in SAR under irrigation (Suarez, 1981; Miyamoto, 1980) require an estimate of leaching fraction, hence the importance of integrating salinity and sodicity responses into a unified soil property model of salt leaching and water movement.

Suarez (1981) developed a model for the SAR of the drainage water at the bottom of the root zone. This point was chosen because it would theoretically reflect the highest SAR reached in the soil profile.

$$\mathrm{SAR_d} = \frac{\dfrac{Na_{iw}}{\mathrm{LF}}}{\left(\dfrac{Mg_{iw}}{\mathrm{LF}} + Ca_d\right)^{0.5}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ 31$$

where

SAR_d	is	SAR of drainage water at the bottom of the root zone
LF	is	leaching fraction
Na_{iw}, Mg_{iw}	are	Na and Mg concentrations in the irrigation water (in mmole/L)
Ca_d	is	Ca concentration in the drainage water

Ca_d is predicted from the ionic strength, HCO_3/Ca ratio, and partial pressure of CO_2. Ca_d values can be calculated from data given by Suarez (1981). Work is currently being undertaken within the Department of Natural Resources to incorporate this type of prediction into the SALFPREDICT model to further improve its ability to predict leaching fraction and root zone salinity under varying water qualities.

An alternative approximate prediction of the effect of sodic irrigation water on the SAR in the root zone is provided by Miyamoto (1980):

$$SAR_d = SAR_{iw}\left(\frac{1}{\mathrm{LF}}\right)^{0.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ 32$$

where

$\mathrm{SAR_d}$	is	SAR of the deep drainage water at the bottom of the root zone
$\mathrm{SAR_{iw}}$	is	SAR of the irrigation water.

Predicting changes in ESP

While changes in the soil salt content under irrigation are reasonably rapid (occurring in a matter of months) for the surface 0.1 m, changes in cation exchange composition in the subsoil may take many years to come to equilibrium. The rate of change is proportional to the quantity of salts added. For example, an application of 530 mm/yr of an irrigation water with an EC of approximately 5 dS/m to a clay soil with a CEC of 50 meq/100 g would contribute an additional 6% of cations to the exchange complex in the top 0.6 m of soil each year.

Relationship between salinity, sodicity and soil properties

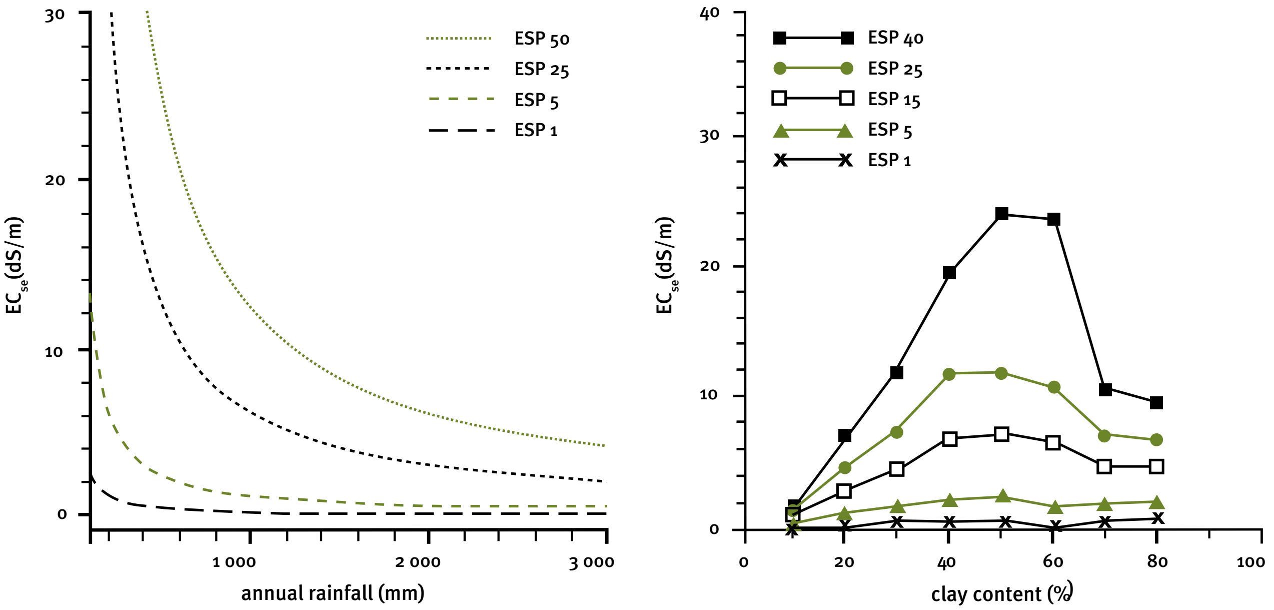
The behaviour of field soils is an integration of salinity and ESP as modified by clay content, clay mineralogy and rainfall (see Figure 50). During soil genesis, the extent of clay migration to void spaces in the matrix determines the 'resistance' of the soil matrix to water movement. The mineralogy of the clay determines the swelling capacity and the ability of the subsoil to restructure and create porosity.

The equilibrium between salt balance, ESP and soil properties explains the differences between field and laboratory responses across a wide range of soils with varying clay contents and clay mineralogies.

Figure 50 summarises the conceptual framework and the main relationships. The relationships are illustrative only, to show the pattern of response. Figure 50(a) shows that soils with low ESP have low EC_{se} due to good leaching, even under relatively low rainfall. Figures 50(b) and 50(c) show the influence of particle packing and clay mineralogy on salt accumulation which is strongly influenced by ESP. From a combination of these two figures, soils with high clay content which are also dominated by montmorillonite mineralogy show lower EC_{se} than lower clay content soils with mixed mineralogy, particularly at ESP values greater than 5. Figure 50(d) shows the effect of rainfall on the equilibrium relationships between ESP and EC_{se}. The range in equilibrium value for a given ESP is related to the water available to move through the restriction of the soil matrix.

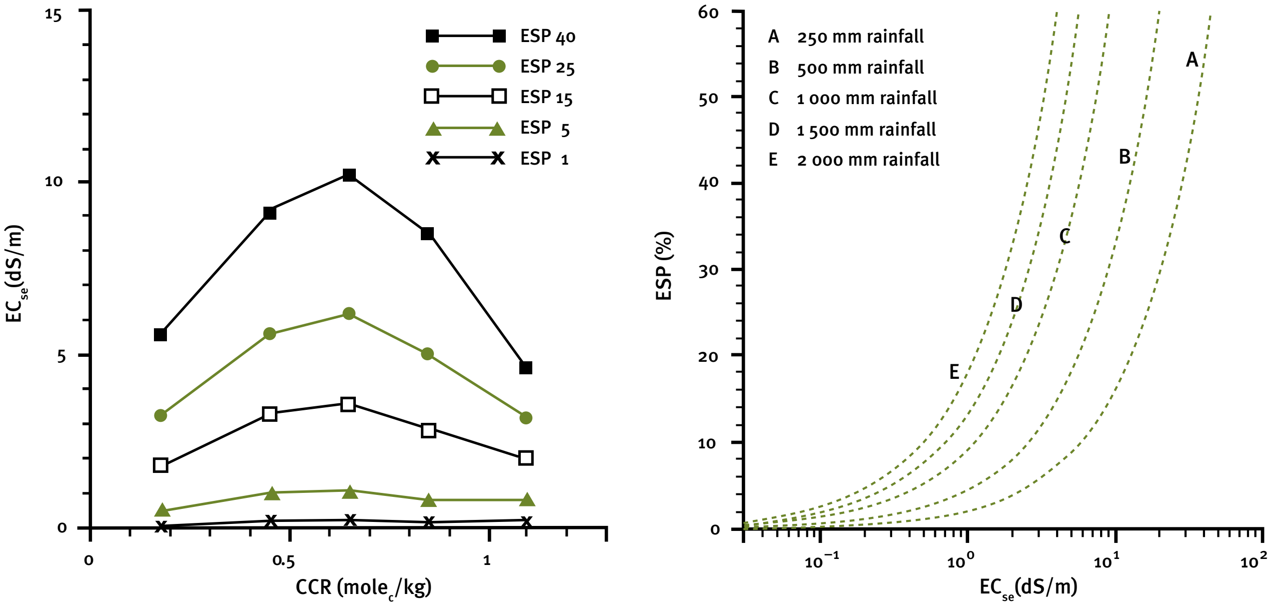
Deep drainage is inversely related to EC_{se}, thus soils with low EC_{se} have high deep drainage for a given water input.

Figure 50. The conceptual framework for the soil salt balance in relation to soil properties, showing the contribution of rainfall and the soil properties of clay content, mineralogy (as CCR) and ESP to subsoil EC_{se}. EC_{se} is the inverse of drainage below the root zone.



(a) Relationship of EC_{se} with rainfall and ESP.

(b) Relationship of EC_{se} with clay content and ESP.



(c) Relationship of EC_{se} with CCR and ESP.

(d) Equilibrium lines for EC_{se} and ESP, and the effect of rainfall.

Other factors in irrigation water quality

In addition to salinity and sodicity, a number of other issues need to be considered when looking at water quality for irrigation, such as plant response to high levels of specific ions or excessive nutrients, and the effect of salt and mineral deposits on plants and on equipment.

Specific ion toxicity

Toxicity problems occur when certain ions in the soil or water are accumulated within the plant at concentrations high enough to cause crop damage or reduced yields.   The degree of damage will depend on the amount of ion uptake and crop sensitivity. The ions of primary concern are chloride, sodium and boron. (Specific ion toxicity is discussed in some detail in Symptoms of salinity and specific ion effects on plants page 53.)

Toxicity can also occur as a result of direct absorption of the toxic ions through leaves wet by overhead sprinklers. Sodium and chloride are the ions most likely to be absorbed through leaves, and toxicity to one or both can be a problem with certain sensitive crops such as citrus.

Excessive nutrients

High nitrogen concentrations in an irrigation water can cause excessive vegetative growth, lodging and delayed crop maturity. Water high in bicarbonate or iron content or containing gypsum and distributed by overhead sprinklers can leave deposits on fruit or leaves.

Equipment problems

Salinity concentrations and precipitates can corrode irrigation equipment and cause scaling. Suspended organic and inorganic sediments can clog gates, sprinkler heads and drippers. More commonly, sediments accumulate in channels and ditches, requiring the costly maintenance of waterways.