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FRESH & MARINE
WATER QUALITY

Draft revised Chapter 4.2

Water Quality for Irrigation and General Water Uses: Guidelines

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DRAFT

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1 Introduction

This Chapter forms an update to an existing Chapter of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000). In particular, this is the updated version of what was known as Chapter 4.2 of the abovementioned guidelines: Water Quality for Irrigation and General Uses. In order to undertake this review, the revised Water Quality Management Framework (WQMF) documentation was reviewed to inform the process. The first two steps of the WQMF involve gaining an understanding of the current knowledge and what it means in terms of the management aims. In this instance, what we know is documented in the current review. In terms of the management aims associated with irrigation water, the goal is to provide good quality water for successful crop production i.e. protect environmental, animal and consumer health by providing water that is safe for a crop/food produce to be irrigated with without adverse effects, and is free of levels of contaminants that will accumulate in plant edible tissues.

Information used to update the guideline values was sourced from the current literature and evaluated for relevance, with preference given to data from Australia and New Zealand. The Chapter entitled 'Water Quality for Irrigation and General Water Uses: Background Information' can be read in conjunction with the present document for more information on guideline derivation.

Agricultural practice in Australia and New Zealand is often dependent on irrigation, because of climatic constraints on crop demand. In Australia particularly, agriculture is predominantly based in areas of limited rainfall, and there is heavy reliance on the use of surface and groundwaters for irrigation of crops and pastures. In 2020, approximately 60% of the water available for human use is used for irrigated agriculture (DAWE 2021) accessed 27/08/2021: <https://www.agriculture.gov.au/water/water-for-food>. Last year, about 5.7 million megalitres were applied to crops and pastures, 1.5 million hectares of agricultural land was irrigated, and 20,700 farms applied water to their land (ABS 2021)

In 2017-18, total Gross Value of Irrigated Agricultural Production (GVIAP) reached \$17.7 billion. The four commodities with the highest GVIAP were fruits and nuts, vegetables, cotton and dairy products. Combined, these four commodities accounted for 69% of total GVIAP for that year (ABS 2019).

In New Zealand irrigation is playing an increasingly important role in agricultural production. The area of irrigated land almost doubled between 2002 and 2019, from 384,000 to 735,000ha, that is, 1.3% of New Zealand's land area (Stats NZ 2021). Irrigated agriculture makes a significant contribution to the New Zealand economy, with irrigation contribution estimated at 2.17 billion 'at the farm gate' in 2012 (NZIER 2014).

An important goal of these Water Quality Guidelines is to maintain the productivity of irrigated agricultural land and associated water resources, in accordance with the principles of ecologically sustainable development and integrated catchment management (see section 1.1). This should be a key consideration in any irrigation strategy, alongside maximum yield and economic viability.

1.1 Philosophy

In developing the guidelines, emphasis has been placed on sustainability in agricultural, which aims to ensure that:

- the supply of necessary inputs is sustainable
- the quality of natural resources is not degraded
- any environmental impacts are minimised to acceptable levels and the environment is not irreversibly harmed (common environmental harm in irrigation is sodicity and salinity which are reversible at some cost)
- the welfare and options of future generations are not jeopardised by the production and consumption activities of the present generation; and
- yields and produce quality are maintained and improved.

In terms of water quality, the focus for sustainable farming systems is on adopting management practices that maintain productivity and minimise the off-farm movement or leaching of potential aquatic contaminants. Key issues include soil erosion, landscape salinity, fertiliser and pesticide management, livestock access to streams, and safe disposal of effluent from intensive animal.

Implementation of best management practices and regulations are important to minimise potential environmental harm, prevent human health issues and maintain sustainability. This can include:

- Development of irrigation hardware and software systems (e.g., precision agriculture)
- Irrigation scheduling to prevent over irrigation that could lead to surface runoff and groundwater contamination
- Development and the application of appropriate guidelines for both irrigation water quantity and quality
- Development of appropriate soil quality guidelines values for managing irrigation activities
- Development of drainage systems for vulnerable irrigation schemes
- Monitoring and assessment of groundwater/surface water impacts.

The guidelines should be used for irrigation water sourced primarily from rainfed natural sources for protection of the soil environment, crop growth and quality, and related natural resources that could be impacted by the use of the irrigation water.

Specific irrigation water quality guidelines for intensive horticultural activities (e.g. hydroponics and glass-house growing), and waste water reuse (recycled water) are not included in this document. The Australian Guideline for Water Recycling (NRMCC et al. 2006) should be considered for irrigation with recycled water.

The guidelines are values below which there should be minimal risk of adverse effects. Further investigation is recommended if a DGV, SGV or trigger value is exceeded, to determine the level of risk.

1.2 Scope

Soil, plant and water resource issues that have been taken into account in developing the water quality guidelines for irrigation use are summarised in Table 1. Factors affecting irrigation water quality concern physical, chemical and biological characteristics that may affect the soil environment, groundwater and crop growth and quality. Irrigation guidelines should not be considered in isolation of aquatic ecosystems when determining acceptable/sustainable irrigation practices. The guidelines should not be the sole reference material to be used in determining the sustainability of irrigation practices. To ensure sustainable outcomes, readers also need to plan their practices and manage operations with regard to water quality guidelines/objectives for other waterway uses/values - including aquatic ecosystems in ground and surface waters.

Table 1 Key issues concerning irrigation water quality effects on soil, plants and water resources

	Key issues
Soil	<ul style="list-style-type: none"> Root zone salinity Soil structural stability Build-up of contaminants in soil Release of contaminants from soil to crops & pastures
Plants	<ul style="list-style-type: none"> Yield Salt tolerance Specific ion tolerance Foliar injury Uptake of toxicants in produce for human consumption Contamination by pathogens
Water resources	<ul style="list-style-type: none"> Deep drainage & leaching below root zone Movement of salts, nutrients & contaminants to groundwaters & surface waters
Important associated factors	<ul style="list-style-type: none"> Quantity and seasonality of rainfall Soil properties Crop and pasture species and management options Land type Groundwater depth and quality

Guidelines are also included for general on-farm water use dealing with the corrosion and fouling potential of waters. These characteristics are important for the maintenance of farm equipment (pumps, pipes, etc.). The guidelines may also be applied more widely where corrosion and fouling are of concern.

Specific irrigation water quality guidelines for intensive horticultural activities (e.g. hydroponics and glass-house growing), and waste water reuse (recycled water) are not included in this document. The Australian Guideline for Water Recycling (NRMCC et al. 2006) should be considered for irrigation with recycled water.

Guidelines for irrigation water quality are given here for biological parameters, salinity and sodicity, inorganic contaminants (i.e. specific ions, including heavy metals and nutrients), organic contaminants (i.e. pesticides) and radiological characteristics. At present PFAS guidelines are not included and the NEMP guideline should be referred to (HEPA 2020). The guidelines are values below which there should be minimal risk of adverse effects. Further investigation is recommended if a DGV, SGV or trigger value is exceeded, to determine the level of risk.

A more detailed discussion of all water quality parameters included in the guidelines is given in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information'.

2 Biological parameters

2.1 Algae

No guideline value for algae in irrigation waters is recommended; however, excessive algal growth may indicate nutrient pollution of the water supply.

Algae are commonly found in most water sources and do not generally cause problems in irrigation waters unless there is excessive growth due to factors such as suitable flow regime, temperature, abundant nutrients and adequate sunlight. The main problem associated with excessive algal growth in irrigation waters is the blockage of distribution and irrigation equipment. This can result in reduced or uneven flow throughout the irrigation system which may reduce crop yield and increase overall maintenance costs.

2.2 Cyanobacteria (blue-green algae)

Algal blooms should be treated as potentially toxic and the water should not be used for irrigation until the algae are identified and the level of toxin determined.

- ***High risk crops:*** *Water contaminated with cyanobacteria should not be sprayed irrigated on vegetables and fruits, or come in contact with plants being grown for food, especially for food that are being eaten raw such as fruits (strawberries, grapes, apples, tomatoes) and leafy vegetables (salads, cabbages, lettuces) and should be avoided if the cell numbers are as follows:*
 - *Microcystis aeruginosa: >50,000 cells/mL, or*
 - *Dolichospermum circinale: >100,000 cells/mL*
- and***
- *10 µg/L total microcystins or*
 - *20 µg/L total saxitoxins*

Where there is no direct water contact with the edible parts of the plant, irrigating with blue-green algae contaminated water is unlikely to be a problem.

- ***Pasture irrigation:*** *Spray irrigation of pasture should be avoided or minimised when the following levels are reached:*
 - *Microcystis aeruginosa: >50,000 cells/mL, or*
 - *Dolichospermum circinale: >100,000 cells/mL*

Stock should be kept off pasture irrigated with blue-green algae-contaminated water for at least two weeks after irrigation.

- ***Occupational exposure:*** *The guideline values proposed for various cyanotoxins are as follows:*
 - *Microcystin LR: 24 µg/L*
 - *Cylindrospermopsin: 6 µg/L*
 - *Saxitoxin: 30 µg/L*

Cyanobacteria (blue-green algae) form part of the natural microbial population in most waterbodies. Under certain natural or human-induced circumstances, toxic blooms can occur and may adversely affect the suitability of waters for irrigation, particularly because toxin residues can potentially accumulate on produce for human or animal consumption. If an algal bloom occurs, it is recommended that an alternative source of irrigation water be used, and that the water be tested for microbial composition and (if necessary) toxicity. There is presently insufficient information available for use in deriving guideline values for cyanobacteria in irrigation water.

2.3 Human and animal pathogens

Default guideline values (DGV) for *Escherichia coli* in irrigation waters used for food and non-food crops are dependant on the intended use and site preventative measures (Table 2)

Table 2 Default guideline values (DGV) for *Escherichia coli* (or thermotolerant coliforms) in irrigation waters used for food and non-food crops^a

Intended Use	Site preventative measures	DGV * (<i>E. coli</i> / 100mL)
Commercial food crops consumed raw or unprocessed	None required, water can be used for all crop applications, including spray irrigation of salad crops	1
Commercial food crops **	If spray irrigation a minimum of 2 days between final irrigation and harvest (no harvesting of wet produce). Above-ground crops with subsurface irrigation. Crops with no ground contact with skins removed before consumption (e.g. Citrus).	100
	No contact of irrigation water or irrigated soil with harvestable part of crop (e.g. apples, apricots, grapes, citrus, nuts), or Crops processed and cooked before consumption (e.g. wine production, potatoes, beetroot).	1000
Livestock drinking water	Water not to be used for consumption by cattle under 12 months of age if the source of water contains animal (e.g. abattoir or saleyard) waste. Monitor and manage algae blooms.	100
Pasture or fodder crop irrigation (including hay, silage, and commercial fodder production).	Limited withholding periods: Exclude lactating dairy cattle from pasture for four hours or until pasture is dry. Suitable for direct grazing by animals with consideration of notes below *	100
	5 day withholding period: Exclude grazing animals for 5 days after irrigation. Fodder dried and ensiled (not for human consumption)	1000

Non-food crops (e.g. trees, woodlots, flowers, cotton)	no access during irrigation. If public potentially in vicinity and spray irrigation a minimum of 25 m buffer to nearest public access is required, this distance should be increased if the prevailing wind direction increases public exposure, or irrigation restricted on days of high wind that could increase public exposure.	10000
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* water sourced from human sewage requires the log reduction values as define in the Australia Guidelines for Water Recycling (NRMMC et al. 2006), helminth controls may also be required as specified for livestock exposure, and supply to pigs is prohibited.

**Production of all food crops should meet the relevant industry food production water quality requirements.

Adapted from AGWR (NRMMC et al. 2006), Median values (refer to discussion on derivation of guidelines below) .

It is generally not feasible nor warranted to test irrigation water for the presence of the wide range of water-borne microbial pathogens that may affect human and animal health. The guidelines recommended here are based on the practicable testing of irrigation waters for the presence of *E.coli* (, which gives an indication of faecal contamination and thus the possible presence of microbial pathogens(NRMMC et al. 2006). However, the test does not specifically indicate presence or absence of pathogenic organisms.

It is recommended that a 95th percentile value of *E.coli* be used, based on a number of readings generated over time from a regular monitoring program. If any individual value exceeds the DGV, a repeat sample should be collected to confirm the exceedance and action taken to determine the source of the contamination, and improve the water quality to acceptable levels.

For helminths, a guideline value of < 1 helminth egg per litre is proposed for the protection of crop consumers, although there is no requirement for monitoring in areas where helminth infections have not been reported or are not expected. Insufficient information is available for use in setting guidelines for protozoa and viruses in irrigation water.

2.4 Plant pathogens

No guideline values for plant pathogens in irrigation waters are recommended at this time. As a general precaution, disinfestation treatment is advisable for water that contains plant pathogens and is to be used for irrigating potentially susceptible plants.

Agricultural crops and pastures can be affected by various plant pathogens transmitted through a number of different pathways including irrigation water, although it is believed that the risk from pathogens in irrigation water is low under most circumstances. However, plant pathogens in irrigation water used for intensive agricultural and horticultural industries (particularly where water is captured and reused) can potentially lead to crop damage and economic loss.

Additional research is required before guidelines can be developed, particularly regarding the efficacy of water-borne plant pathogens on a wide range of crops.

3 Irrigation salinity and sodicity

To assess the salinity and sodicity of water for irrigation use, a number of interactive factors must be considered. As outlined in this section, these include irrigation water quantity and quality, soil properties, plant salt tolerance, climate, landscape (including geological and hydrological features), and water and soil management.

Salinity is the presence of soluble salts in or on soils, or in waters. High salinity levels in soils may result in reduced plant productivity or, in extreme cases, the elimination of crops and native vegetation. Salinity related issues are of concern in many parts of Australia but salinisation is currently considered to be only of minor importance in New Zealand.

Sodicity is the presence of a high proportion of sodium (Na^+) ions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in soil or water. Sodicity degrades soil structure by breaking down clay aggregates, which makes the soil more erodible and less permeable to water, and reduces plant growth.

The effects of salinity and sodicity in irrigation waters are very situation-specific, making it inappropriate to set water quality guideline values for general application. Factors which need to be considered include: the type of crop being cultivated and its salt tolerance, the characteristics of the soil under irrigation, soil management and water management practices, climate and rainfall (Figure 1).

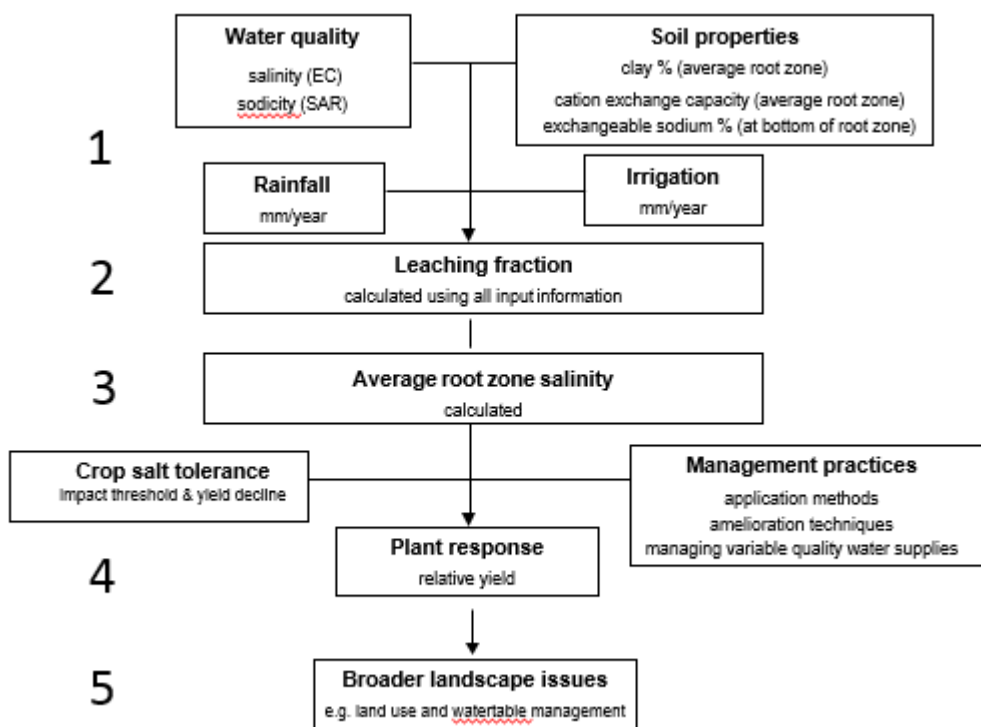


Figure 1 Flow diagram for evaluating salinity and sodicity impacts of irrigation water

There are five key steps to determining the suitability of irrigation water with respect to salinity and sodicity (Figure 1). Prior to the following steps, the crop selection comes first. Generally, irrigators start with the crop selection (for instance a grower is growing lettuce, or pomegranates or grapes, etc, and their respective rootzone threshold salinity is known) the leaching fraction in order to maintain suitable root zone salinity conditions, and finally a consideration of where the salt moves. The Leaching Fraction requirement is calculated using the following steps:

- Step 1:** Identify the soil properties, water quality, climate (rainfall) and management (irrigation application rates) practices for the site in question.
- Step 2:** Estimate the leaching fraction under the proposed irrigation regime using approaches outlined in this section.
- Step 3:** Estimate the new average root zone salinity as outlined in this section. Average root zone salinity is considered the key metric to assess plant growth in response to salinity and sodicity levels in the irrigation water. However, poor soil structure can also reduce plant yields by limiting aeration, water infiltration and availability and root growth. The likelihood of soil structural problems induced by irrigation can be predicted from guideline values derived in this section.
- Step 4:** Estimate relative plant yield (although note that the impact of salinity and sodicity can be modified by management practices as discussed later in this section).
- Step 5:** Consider salinity and sodicity problems within the framework of broader catchment issues such as rising regional watertables, groundwater pollution and surface water quality. Watertable salinity (capillary rise) develops because shallow water tables-soil hydraulic characteristics and evaporative demand interact to cause the upward movement of salt. It is the greatest threat to the ongoing sustainability of most irrigation schemes in the world.

Software *SALF2* (replacing *SALF PREDICT*) estimates the parameters necessary for a detailed assessment of irrigation water quality in relation to soil properties, rainfall, water quality and plant salt tolerance. The software is based on summer rainfall areas and needs to be used with some caution in winter rainfall areas. It incorporates many of the detailed algorithms included in this Section. Copies of the software may also be obtained from the its author Dr Roger Shaw or the Queensland Government website: Salinity management handbook | Publications | Queensland Government.

A simple initial assessment can be made by measuring the electrical conductivity (EC_i measured as $EC_{1:5}$) and concentrations of sodium (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) in irrigation water. Note that EC is expressed in units of dS/m throughout Section 3 (1 dS/m = 1000 μ S/cm).

The three measures of electrical conductivity are (DERM 2011) :

- $EC_{1:5}$: the electrical conductivity of a 1:5 soil water suspension, used routinely in analyses
- EC_{se} : the electrical conductivity of the soil saturation extract, used for predicting plant response (commonly predicted from 1:5 and soil properties, or can be measured directly)
- EC_s : the electrical conductivity of soil at measured or predicted maximum field water content (approximating field capacity), used to assess salt movement through the soil (usually predicted from 1:5 and soil properties)

3.1 Determining the suitability of irrigation water salinity for a crop

Calculate the average root zone salinity (EC_{se}) from EC_i and the average root zone leaching fraction (LF), to see if a crop is likely to be affected by the irrigation water salinity. First, estimate the LF of the soil being irrigated (i.e. the proportion of applied water that leaches below the root zone). Approximate average LF values for four broad soil types are listed in Table 3. Then calculate EC_{se} using the following equation:

$$EC_{se} = \frac{EC_i}{2.2 \times LF} \quad \text{Equation 1}$$

where:

EC_{se} = average root zone salinity in dS/m

EC_i = electrical conductivity of irrigation water in dS/m

LF = average leaching fraction.

Table 3 Soil type and average root zone leaching fraction^a

Soil type	Average root zone LF
Sand	0.6
Loam	0.33
Light clay	0.33
Heavy clay	0.2

^a From DNR (1997a), adapted from DNR (1997b)

Then use the EC_{se} value to assess the general level of crop tolerance to the irrigation water salinity by comparing it with the values in Table 4. Alternatively, compare the EC_{se} with the relative salt tolerances of specific crop and pasture species provided here in Table 5 and in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information', Section 3.2.4, Table 14.

Table 4 Soil and water salinity criteria based on plant salt tolerance groupings

Plant salt tolerance groupings	Water or soil rating	Average root zone salinity, EC_{se} (dS/m)
Sensitive crops	Very low	<0.95
Moderately sensitive crops	Low	0.95-1.9
Moderately tolerant crops	Medium	1.9-4.5
Tolerant crops	High	4.5-7.7
Very tolerant crops	Very high	7.7-12.2
Generally too saline	Extreme	>12.2

Adapted from DNR (1997b)

A list of the relative salt tolerances of a limited selection of common field crop, pasture and horticulture species is provided in Table 5.

Information in this table is derived from data currently available in the literature, but preference should be given to locally derived data where available. This gives approximate values of average root zone salinities at the threshold level (the level causing yield reduction). It also shows electrical conductivity of irrigation water at the threshold level for a range of soil types, but it is meant as a general guide only.^a If at all uncertain about salt tolerance or the effect of irrigation water quality on soil structure, submit a soil sample for analysis and seek expert advice.

a See also Section 3 in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information'

3.2 Determining the risk of soil structure degradation caused by irrigation water quality

Calculate the Sodium Adsorption Ratio (SAR) and use it (with EC_i) to predict soil structure stability in relation to irrigation water. The SAR value measures the relative concentration of sodium (Na⁺) to calcium (Ca²⁺) and magnesium (Mg²⁺) and can be calculated from the following equations:

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2}}} \quad \text{Equation 2}$$

Where Na⁺, Ca²⁺ and Mg²⁺ are expressed in mmole_c/L (where subscript c indicates charge). SAR is dimensionless

In mg/L, the equation becomes:

$$\text{SAR} = \frac{\frac{\text{Na}}{23}}{\sqrt{\frac{\frac{\text{Ca}}{20} + \frac{\text{Mg}}{12.2}}{2}}} \quad \text{Equation 3}$$

Where units for Na, Ca and Mg are in mg/L

Evaluate the quality of the irrigation water by superimposing its EC_i and SAR values on Figure 2, to see if it will affect soil structure (through clay aggregate breakdown). Water quality that falls to the right of the dashed line is unlikely to cause soil structural problems. Water quality that falls to the left of the solid line is likely to induce degradation of soil structure; corrective management will be required (e.g. application of lime or gypsum). Water that falls between the lines is of marginal quality and should be treated with caution. This is useful as a general guide to understand areas of threshold electrolyte concentrations beyond which dispersion will occur but the “shape” of these curves is soil dependant and should not be considered as an absolute guide for irrigation.

Table 5 Tolerance of plants to salinity in irrigation water^a

Common name	Scientific name	Average root zone salinity threshold (ECse) (dS/m) ^b	sand	loam	clay
Field Crops					
Barley, grain	<i>Hordeum vulgare</i>	8.0	12.6	7.2	4.2
Cotton	<i>Gossypium hirsutum</i>	7.7	12.1	6.9	4.0
Beet, sugar	<i>Beta vulgaris</i>	7.0	11.0	6.3	3.7
Sorghum	<i>Sorghum bicolor</i>				3.1
Wheat	<i>Triticum aestivum</i>				3.1
Sunflower	<i>Helianthus annuus</i>	5.5	7.5	4.3	2.5
Oats	<i>Avena sativa</i>		7.0	4.0	2.3
Soybean	<i>Glycine max</i>	5	7.0	4.0	2.3
Peanut	<i>Arachis hypogala</i>	3.2	4.4	2.5	1.5
Rice, paddy	<i>Oryza sativa</i>	3	4.8	2.7	1.6
Corn, grain, sweet	<i>Zea mays</i>	1.7	3.2	1.8	1.1
Sugarcane	<i>Saccharum officinarum</i>	1.7	4.3	2.5	1.4
Fruits					
Olive	<i>Olea europaea</i>	4	5.1	2.9	1.7
Macadamia seedling		3.6	4.6	2.6	1.5
Peach	<i>Prunus persica</i>	3.2	4.7	2.7	1.6
Rockmelon	<i>Cucumis melo</i>	2.2	4.6	2.6	1.5
Grapefruit	<i>Citrus paradisi</i>	1.8	3.0	1.7	1.0
Orange	<i>Citrus sinensis</i>	1.7	2.9	1.7	1.0
Grape	<i>Vitis</i> spp.	1.5	3.3	1.9	1.1
Avocado	<i>Persea americana</i>	1.3	2.3	1.3	0.8
Apple	<i>Malus sylvestris</i>	1	2.0	1.2	0.7
Pastures					
Wheatgrass, tall	<i>Agropyron elongatum</i>	7.5	12.5	7.2	4.2
Rhodes grass, Pioneer	<i>Chloris gayana</i>	7	12.8	7.3	4.2
Couch grass	<i>Cynodon dactylon</i>	6.9	10.8	6.1	3.6
Buffel grass, Gayndah	<i>Cenchrus ciliaris</i> var <i>Gayndah</i>	5.5	8.2	4.7	2.7
Phalaris	<i>Phalaris tuberosa</i> (<i>aquatica</i>)	4.2	5.3	3.0	1.8
Fescue	<i>Festuca clatior</i>	3.9	7.3	4.2	2.4
Green panic, Petri	<i>Panicum maximum</i>	3	5.6	3.2	1.8
Townsville stylo	<i>Stylosanthes humilis</i>	2.4	3.7	2.1	1.2
Clover, Berseem Clover	<i>Trifolium alexandrinum</i>	2	3.8	2.2	1.3
Lucerne, Hunter River	<i>Medicago sativa</i>	2	4.7	2.7	1.6
Clover, strawberry (Palestine)	<i>Trifolium fragiferum</i>	1.6	3.3	1.9	1.1
Snail medic	<i>Medicago scutellata</i>	1.5	2.9	1.7	1.0
Clover, white (New Zealand)	<i>Trifolium repens</i>	1	2.5	1.4	0.8
Vegetables					
Zucchini	<i>Cucurbita pepo melopepo</i>	4.7	7.3	4.2	2.4
Beet, garden	<i>Beta vulgaris</i>	4	6.5	3.7	2.1
Broccoli	<i>Brassica oleracea</i>	2.8	4.9	2.8	1.6
			4.2	2.4	1.4

Pea	<i>Pisum sativum</i> L.	2.5	3.2	1.8	1.1
Tomato	<i>Lycopersicon esculentum</i>	2.3	3.5	2.0	1.2
Potato	<i>Solanum tuberosum</i>	1.7	3.2	1.8	1.1
Pepper	<i>Capsicum annum</i>	1.5	2.8	1.6	0.9
Lettuce	<i>Lactuca sativa</i>	1.3	2.7	1.5	0.9
Onion	<i>Allium cepa</i>	1.2	2.3	1.3	0.8
Eggplant	<i>Solanum melongena</i>	1.1	3.2	1.8	1.1
Bean	<i>Phaseolus vulgaris</i>	1	1.9	1.1	0.6
Carrot	<i>Daucus carota</i>	1	2.2	1.2	0.7

a From DNR (1997a), adapted from DNR (1997b)

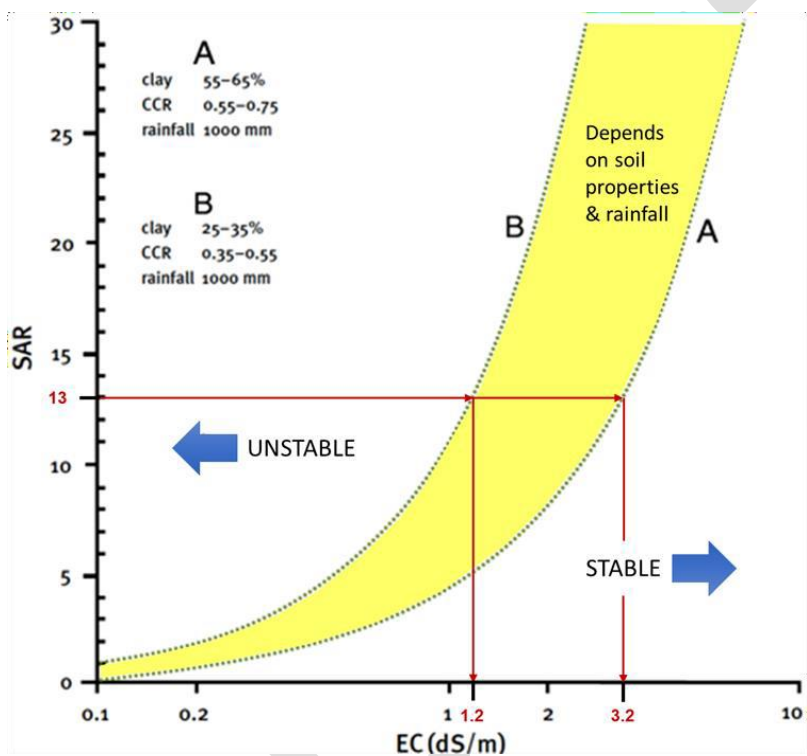


Figure 2 Relationship between SAR and EC of irrigation water for prediction of soil structural stability

Adapted from DNR (1997)

4 Major ions of concern for irrigation water quality

4.1 Bicarbonate

No guideline value is recommended for bicarbonate in irrigation waters.

Elevated levels of bicarbonate in irrigation waters can adversely affect irrigation equipment, soil structure and crop foliage. These problems occur when the bicarbonate (or carbonate) in solution with calcium is sufficient to exceed the solubility of calcium carbonate. The precipitation of calcium carbonate can lead to white scale formation on leaves and fruit and may clog irrigation equipment.

The same process can give rise to precipitates of calcium carbonate in soil. This will effectively increase the sodium adsorption ratio (SAR) or exchangeable sodium percentage (ESP) and may lead to soil structural problems. An overview of the effect of irrigation with waters of high SAR is given in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information' (Section 3).

4.2 Chloride

Issues concerning chloride in irrigation waters relate to the risk of: (1) foliar injury to crops; (2) salty taste and (3) increased uptake by plants of cadmium from soil. These are discussed more fully in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information', Section 4.2.

4.2.1 Foliar injury

Guideline values for prevention of foliar injury due to chloride in irrigation water from sprinkler application are provided in Table 6.

Chloride in irrigation water can reduce the quality of tobacco leaf. Chloride concentrations >40 mg/L are considered unsuitable for irrigation of tobacco and some reduction in quality may occur with concentrations in the range 25 to 40 mg/L (Gill 1986).

Table 6 Chloride concentrations (mg/L) causing foliar injury in crops of varying sensitivity^a

Sensitive <175	Moderately sensitive 175-350	Moderately tolerant 350-700	Tolerant >700
Almond	Pepper	Barley	Cauliflower
Apricot	Potato	Maize	Cotton
Citrus	Tomato	Cucumber	Sugarbeet
Plum		Lucerne	Sunflower
Grape		Safflower	
		Sorghum	

^a After Maas (1990)

4.2.2 Salty taste

Chloride accumulation in the plant can result in a salty taste, which affects crop markets negatively. Chloride accumulation in berries in the case of grape juice or wine, is detrimental, conferring the product a salty taste and in some cases, leading to its impossibility to sell. Research linking irrigation water EC or soil EC to grape juice or wine quality are limited. However, studies investigating the sensory impacts from chloride in wine indicated a lower threshold for white and red wine juices and wine product is 133 mg/L of chloride.

Interaction between chloride in irrigation water and cadmium in soil

Guideline values for assessing chloride levels in irrigation water with respect to increased cadmium uptake by crops are provided in Table 7.

Table 7 Risks of increasing cadmium concentrations in crops due to chloride in irrigation waters^a

Irrigation water chloride (mg/L)	Risk of increasing crop cadmium concentrations
0-350	Low
350-750	Medium
>750	High

^a McLaughlin et al. (1999)

If high chloride concentrations are present in irrigation water, it is recommended that produce is tested for cadmium concentration in the edible portions (e.g. tubers for potatoes, leaves for leafy vegetables, grain for cereals, etc.).

4.3 Sodium

Guideline values for prevention of foliar injury due to sodium in irrigation water from sprinkler application are provided in Table 8.

Guideline values for specific toxicity effects are provided in Table 9.

Table 8 Sodium concentration (mg/L) causing foliar injury in crops of varying sensitivity^a

Sensitive <115	Moderately sensitive 115-230	Moderately tolerant 230-460	Tolerant >460
Almond	Pepper	Barley	Cauliflower
Apricot	Potato	Maize	Cotton
Citrus	Tomato	Cucumber	Sugarbeet
Plum		Lucerne	Sunflower
Grape		Safflower	
		Sesame	
		Sorghum	

^a After Maas (1990)

Table 9 Effect of sodium expressed as sodium adsorption ratio (SAR) on crop yield and quality under non-saline conditions^a

Tolerance to SAR and range at which affected	Crop	Growth response under field conditions
Extremely sensitive SAR = 2–8	Avocado Deciduous fruits Nuts Citrus	Leaf tip burn, leaf scorch
Sensitive SAR = 8–18	Beans	Stunted growth
Medium SAR = 18–46	Clover Oats Tall fescue Rice Dallis grass	Stunted growth, possible sodium toxicity, possible calcium or magnesium deficiency
High SAR = 46–102	Wheat Cotton Lucerne Barley Beets Rhodes grass	Stunted growth

^a After Pearson (1960); SAR = Sodium Adsorption Ratio (see Section 3)

5 Metals and metalloids

Default guideline values (DGV) and Short-term guideline values (SGV), as defined in the scope (Section 1.2), for metals and metalloids in irrigation water are presented in Table 10. Concentrations in irrigation water should be less than the recommended guideline values.

Table 10 Agricultural irrigation water default guideline value (DGV), short-term guideline value (SGV) and soil added contaminant loading limit (ACL) guideline values for heavy metals and metalloids^a

Element	ACL ^b (kg/ha)	DGV (mg/L)	SGV (mg/L)
Aluminium	ND	5	20
Arsenic	20	0.1	2.0
Beryllium	ND	0.1	0.5
Boron	ND	0.5	0.75 to 15
Cadmium	2	0.01	0.05
Chromium	ND	0.1	1
Cobalt	ND	0.05	0.1
Copper	140	0.2	5
Fluoride	ND	1	2
Iron	ND	0.2	10
Lead	195	0.2	2
Lithium	ND	0.075 (Citrus crops)	0.075 to 2.5
Manganese	ND	0.2	10
Mercury	2	0.002	0.002
Molybdenum	ND	0.01	0.05
Nickel	85	0.2	2
Selenium	10	0.02	0.05
Uranium	ND	0.01	0.1
Vanadium	ND	0.1	0.5
Zinc	300	2	5

a Guideline values should only be used in conjunction with information on each individual element and the potential for off-site transport of contaminants (Chapter 'Background information for water quality for irrigation and general water uses', Section 5)

b ND = Not determined; insufficient background data to calculate ACL

a See Chapter 'Water Quality for Irrigation and General Water Uses: Background Information', Section 5.2

The *Default guideline value* (DGV) is the maximum concentration (mg/L) of contaminant in the irrigation water which can be tolerated within the scope of this guideline (Section 1.2) assuming 100 years of irrigation, based on the irrigation loading assumptions described in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information', Section 5.2.

The *short-term guideline value* (SGV) is the maximum concentration (mg/L) of contaminant in the irrigation water which can be tolerated for a shorter period of time (20 years) assuming the same maximum annual irrigation loading to soil as for DGV, or considering site specific related environment, receptors and exposure.

The DGV and SGV values have been developed: (1) to minimise the build-up of contaminants in surface soils during the period of irrigation; (2) to prevent the direct toxicity of contaminants in irrigation waters to standing crops; and (3) uptake of unacceptable concentrations of the contaminant in the crop. Where DGV and SGV have been set at the same value, the primary concern is the direct toxicity of irrigation water to the standing crop (e.g. for lithium and citrus crops), rather than a risk of contaminant accumulation in soils and plant uptake.

The guideline value for contaminant concentration in soil is defined as the *Added contaminant loading limit* (ACL). The ACL is the maximum contaminant loading in soil defined in gravimetric units (kg/ha) and indicates the cumulative amount of contaminant added from irrigation, above which site-specific risk assessment is recommended if irrigation and contaminant addition is continued.

Once the ACL has been reached, it is recommended that a soil sampling and analysis program be initiated on the irrigated area, and an environmental impact assessment of continued contaminant addition be prepared. As background concentrations of contaminants in soil may vary with soil type, and contaminant behaviour is dependent on soil texture, pH, salinity, etc., it should be noted that ACLs may be overly protective in some situations and less protective in others. The ACL is designed for use in soils with no known history of contamination from other sources. When it is suspected that the soil is contaminated before commencement of irrigation, background levels of contaminants in the soil should be determined and the ACL adjusted accordingly.

The guideline values assume that irrigation water is applied to soils and that soils may reduce contaminant bioavailability by binding contaminants and reducing concentrations in solution. Therefore, they may not be suitable for plants grown in soil-less media (hydroponics or similar methods). The guideline values should only be used in conjunction with the discussion in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information', Section 5 on each individual element and the potential for off-site transport of contaminants. The assumptions underlying these guideline values are recognised internationally as a basis for developing irrigation water quality guidelines.

6 Nitrogen and Phosphorus

Default guideline values (DGV) and Site-specific guideline values (SGV) for nitrogen and phosphorus in irrigation water are presented in Table 11. They are based on maintaining crop yield, preventing bio-clogging of irrigation equipment and minimising off-site impacts. Concentrations in irrigation water should be less than the recommended guideline values.

Table 11 Agricultural irrigation water default guideline value (DGV) and site-specific guideline value (SGV) guidelines for nitrogen and phosphorus

Element	DGV (mg/L)	SGV (mg/L)
Nitrogen	5	15 to 120 ^a
Phosphorus	0.05 ^b	as calculated

^a Requires site-specific assessment (see Section 6 in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information')

^b To minimise bio-clogging of irrigation equipment only

Developing site specific guidelines for major nutrients (nitrogen and phosphorus) for irrigation water is not trivial. This can be compounded by fertiliser applications. The different objectives are often conflicting and derived from different dimensions i.e., crop yield, economic, environmental, biophysical, and social. Sometimes market forces are blamed for excessive irrigation and fertiliser uses that result in adverse environmental consequences. This is a complex system and often site-specific condition must be

considered. For example, irrigation in Great Barrier Reef catchments should focus on minimising/preventing nutrient, sediment, and agrochemical movements into the Great Barrer Reef Marine Park.

The concepts of Default guideline value (DGV) and Site-specific guideline value (SGV) developed for metals and metalloids have also been used to develop guidelines for phosphorus (P) and nitrogen (N).

Excess quantities of N can lead to leaching of N into groundwater and surface water, over-stimulation of plant growth (decreasing yields) and stimulation of algal growth in surface water. The DGV for nitrogen has been set at a concentration low enough to ensure no decreases in crop yields or quality occur. The SGV range for nitrogen has been set to minimise the risk of contaminating groundwater and surface water and requires site-specific information^a which considers the crop that is being grown, environmentally significant concentrations, and gaseous losses.

Phosphorus is often the nutrient that stimulates rapid growth of many microorganisms (i.e. algal blooms). The DGV for P has been set to prevent algal growth in irrigation water. The SGV range for P has been set considering the fertiliser value of phosphorus in water, target phosphorus concentrations in soil, and phosphorus sorption/retention capacities of soils.^b

The guideline values provided in Table 11 should only be used in conjunction with the discussion contained in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information', Section 6.

a See Section 6.1 in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information'.

b method of calculating a site- specific SGV is outlined in Section 6.1 in Chapter 'Water Quality for Irrigation and General Water Uses: Background Information'

7 Organic matter

In some situations, the irrigation water may contain more organic matter than the soil can assimilate, causing the clogging of pores and anaerobic conditions to develop therefore impeding the soil microbial processes and plant root development. This is particularly the case when irrigating with effluent. The NSW guideline for the use of effluent for irrigation (NSW DEC 2004) specifies that an average loading rate of 1500kg/ha/month can be taken as the maximum organic loading for most soils. The minimum irrigation area required based on organic loading can be estimated as follows:

$$\text{Minimum irrigation area } A = CQ / (1,000 \times Lc)$$

Equation 4

Where:

A = irrigation area (ha)

C = concentration of BOD₅ (mg/L)

Q = average effluent flow rate (kL/month)

Lc = critical loading rate of constituent (kg/ha/month)

8 Pesticides

Guideline values for pesticides in irrigation water are listed in Table 12. They consider likely adverse effects of herbicides on crop growth but do not consider potential impacts on aquatic ecosystems. They are based on relatively limited information and include only a subset of herbicides (and no other pesticides) that might be found in irrigation waters.

Table 12 Guideline value concentrations for a range of herbicides registered in Australia for use in or near waters^a

Herbicide	Residue limits in irrigation water	Hazard to crops from residue in water ^c	Crop injury threshold in irrigation water (mg/L)
Acrolein	0.1 mg/L	+	Flood or furrow: beans 60, corn 60, cotton 80, soybeans 20, sugar-beets 60. Sprinkler: corn 60, soybeans 15, sugar-beets 15
Amitrol	0.002 mg/L	++	Lucerne 1600, beans 1200, carrots 1600, corn 3000, cotton 1600, grains sorghum 800
Asulam		++	
Atrazine	10 µg/L	++	
Bromacil	0.2 µg/L	+++	
Chlorpyrifos			
Chlorthiamid ^d		++	
Copper sulfate		+	Apparently above concentrations used for weed control
2,4-D		++	Field beans 3.5–10, grapes 0.7–1.5, sugar-beets 1.0–10
Diazinon			
Dicamba	0.006 µg/L	++	Cotton 0.18
Dichlobenil		++	Lucerne 10, corn 10, soybeans 1.0, sugar-beets 1.0–10, corn 125, beans 5
Diquat		+	
Diuron	0.002 mg/L	+++	
2,2-DPA (Dalapon)	0.004 mg/L	++	Beets 7.0, corn 0.35
Endosulfan			
Fosamine ^d		+++	
Fluometuron		++	Sugar-beets, alfalfa, tomatoes, squash 2.2
Glyphosate		+	
Hexazinone		+++	
Karbutilate ^d		+++	
Malathion			
Metolachlor			
Molinate		++	

Paraquat		+	Corn 10, field beans 0.1, sugar-beets 1.0
Picloram		+++	
Propanil	0.5 µg/L	++	Alfalfa 0.15, brome grass (eradicated) 0.15
Simazine	0.5 µg/L	++	
TCA (Trichloroacetic Acid)		+++	0.5
Terbutryne		++	
Thiobencarb			
Triclopyr		++	
Trifluralin			

a From ANZECC (1992). These should be regarded as interim guideline values only.

b Hazard from residue at the expected maximum concentration: + = low, ++ = moderate, +++ = high.

c Pesticide not registered or approved anymore by APVMA as of April 2021

9 Radiological quality of irrigation water

Guideline values for the radiological quality of agricultural waters are given in Table 13.

Radioactive contaminants can originate from both natural and artificial sources and can potentially be found in surface waters and groundwaters. The main risks to human health due to radioactivity in irrigation water arise from the transfer of radionuclides to crop and animal products for human consumption. Cancer is a potential health hazard for humans associated with exposure to radionuclides in irrigation water.

Table 13 Guideline values for radioactive contaminants for irrigation water

Radionuclide	Guideline value
Radium 226	5 Bq/L
Radium 228	2 Bq/L
Uranium 238	0.2 Bq/L
Gross alpha	0.5 Bq/L
Gross beta (excluding K-40)	0.5 Bq/L

10 General water uses

10.1 pH

To limit corrosion and fouling of pumping, irrigation and stock watering systems, pH should be maintained between 6 and 8.5 for groundwater systems and between 6 and 9 for surface water systems. These lower SGV (LSGV) and lower DGV (LDGV) have been set with upper guideline values (DGV and SGV) to define the range of the guideline for pH (Table 14).

Table 14 Guideline values for pH to limit corrosion and fouling from irrigation water

Parameter	LSGV	LDGV	DGV	SGV
pH	5.0	6.0	8.5	9.0

The pH of water is a measure of its acidity or alkalinity. Generally, pH itself is not a water quality issue of concern, but it can indicate the presence of a number of related problems, for example limiting nutrient availability for crops. The greatest hazard with high or low pH is the potential for deterioration as a result of corrosion or fouling (See GVs below). Values between 5 and 6 should be regarded with caution and a pH >6 should be maintained to reduce the potential for corrosion. The upper pH limit for groundwaters should be slightly lower than for surface waters because of the increased potential for encrustation and fouling. Soil and animal health will not generally be affected by water with pH in the range of 4–9, in the short-term.

10.2 Corrosion

Guideline values for assessing the corrosiveness of water are given in Table 15.

Table 15 Corrosion potential of waters on metal surfaces as indicated by pH, hardness, Langelier index, Ryznar index and the log of chloride: carbonate ratio

Parameter	Value	Comments
pH	<5	High corrosion potential
	5 to 6	Likelihood of corrosion
	>6	Limited corrosion potential
Hardness	<60mg/L CaCO ₃	Increased corrosion potential
Langelier Index	<-0.5	Increased corrosion potential
	-0.5 to 0.5	Limited corrosion potential
Ryznar Index	<6	Limited corrosion potential
	>7	Increased corrosion potential
Log of chloride to carbonate ratio	>2	Increased corrosion potential

^a For further information on these parameters refer to Chapter 'Water Quality for Irrigation and General Water Uses: Background Information'. Section 10.2.

Corrosion of pumping, irrigation and stock watering equipment is a common problem in many agricultural areas of Australia, particularly where groundwater sources are used. It often results in the deterioration of well and pumping equipment, pipelines, channels, sprinkler devices and storage tanks, leading to decreased or uneven water distribution. Corrosion can be caused by chemical, physical or microbiological processes acting on metal surfaces in contact with water. Plastics and concrete may also deteriorate, through processes similar to corrosion, if elevated levels of certain constituents are present.

10.3 Fouling

Guideline values for assessing the fouling potential of water are given in Table 16

Table 16 Fouling potential of waters as indicated by pH, hardness, Langelier index, Ryznar index and the log of chloride: carbonate ratio

Parameter ^a	Value	Comments
pH	<7	Limited fouling potential
	7 to 8.5	Moderate fouling potential (groundwater) ^b
	>8.5	Increased fouling potential (groundwater) ^c
Hardness	>200mg/L CaCO ₃	Increased fouling potential
Langelier Index	>0.5	Increased fouling potential
	-0.5 to 0.5	Limited fouling potential
Ryznar index	<6	Increased fouling potential
	>7	Limited fouling potential
Log of chloride to carbonate ratio	<2	Increased fouling potential

a For further information on these parameters refer Chapter 'Water Quality for Irrigation and General Water Uses: Background Information'. Section 10.3

b For surface waters, pH range 7 to 9

c For surface waters, pH >9

Fouling of agricultural water systems can lead to decreased water quality and yield as a result of clogging, encrustation and scaling. All parts of the system can be affected including wells, pumping equipment, pipes and sprinklers. The main causes of fouling in agricultural water systems can be attributed to physical, chemical and biological properties of the water.

10.4 Agricultural chemical preparation

Insufficient information is available to set guideline values for water used to prepare agricultural chemicals.

Water is the most common additive and diluent used in the preparation of agricultural chemicals (e.g. pesticides, stock dips and fertilisers) for on-farm use. Although some agricultural chemicals can withstand a range of water qualities before performance is substantially affected, it is recommended that good quality water be used to ensure the desired result.

To check that a particular water is suitable for use with an agricultural chemical, it is best to make up and test a trial solution first. Specific details on water quality requirements should be noted from the product label or by contacting the manufacturer.

11 Conclusion

The information provided in this Chapter has considered the parameters that needed to be reviewed in line with current international recommendations, to adopt a more conservative guideline value when necessary. However, it is important to note that the values are not necessarily appropriate for all situations. Producers should not experience economic losses from treating water to an unnecessary standard for their production system. Such an approach is in line with the revised water quality management framework which considers a cyclical process that adapts with new information and specific site water quality objectives.

Some additional work is recommended for some parameters presented. The specific recommendations for each water quality parameter are detailed in the chapter 'Water Quality for Irrigation and General Water Uses: Background Information'.

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13 Glossary of terms

The Glossary of terms is provided at the end of Chapter 'Water Quality for Irrigation and General Water Uses: Background Information'.

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