2.10 Irrigation salinity and water quality

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Key points

- Measure soil and water salinity levels on a regular basis to observe trends and identify problems
- Salinisation causes nutritional and osmotic stress on the crop, whereas sodification causes soil structural destabilisation leading to waterlogging.
- Poor quality water can be used for irrigation if appropriate management practices are put into place. These include:
  - Using a higher leaching fraction, with consequently reduced crop WUE.
  - Improving soil structure and soil organic matter, and by supplying appropriate nutrients
  - Avoiding irrigating with poor quality water during the most sensitive stages of crop growth.
  - Using salt tolerant cotton varieties.
  - Diluting (or "shandying") poor quality water with water of a higher quality .

What is salinisation in agriculture?

Salinisation results from the accumulation of soluble salts in the root zone. These salts may be important dissolved salts including cations, such as sodium (Na), calcium (Ca), magnesium (Mg), and potassium (K), and anions such as carbonate (HCO_3), sulfate (SO_4) and chloride (Cl).

In the Australian environment, large quantities of stored salts have accumulated naturally from several sources, including:

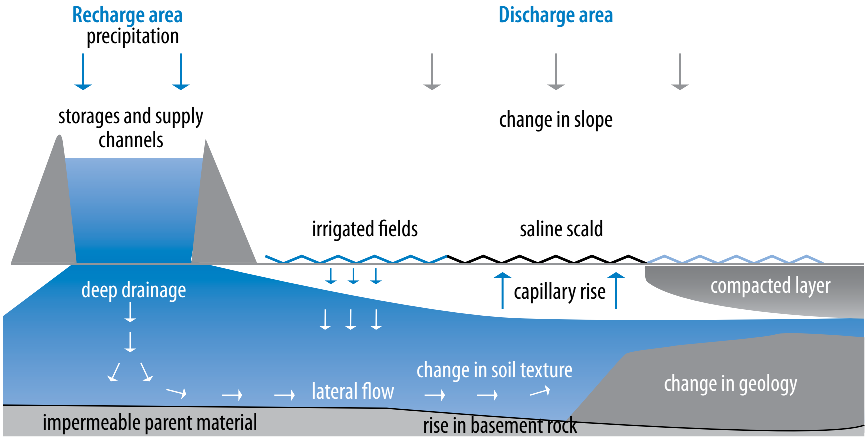
- cyclical deposition through rainfall
- weathering of saline materials, and
- salts stored in the soil or laid down as marine sediments in earlier geological times.

Areas of salinisation are primarily associated with the arid and semi-arid landscapes. These semi-arid and arid areas provide good climatic conditions but, unfortunately, the vagaries of rainfall render them mostly unsuitable for crop production. Irrigation overcomes this, but inefficient irrigation practices usually result in mobilisation of stored salts into the root zone. This is termed **irrigation salinity**.

In terms of agriculture, the other main type of salinisation is **dryland salinity**. Typically it occurs when native vegetation is replaced with pastures or cropping. As a result, less water is used, with the remainder draining beyond the root zone. The excess water (termed **deep drainage**) often recharges groundwater and may cause watertables to rise if the water is unable to flow vertically or laterally because of a change in texture or geology or other obstruction. Any salts stored between the root zone and the groundwater are mobilised in this process and brought to the surface. Through capillary action, salts accumulate and in time will be concentrated enough to cause a reduction in productivity. The capillary rise effect occurs when the dry soil above a watertable draws the groundwater up in much the same way as a sponge sitting on a wet surface soaks up water. The water then evaporates on the surface, leaving the salts behind both in and on the surface soils where they inhibit plant root growth. (See also SOILpak, page D4-5.)

As with dryland salinity, irrigation salinity is the result of significant changes to the hydrological balance in a given area. If irrigation plus rain exceeds evaporation, transpiration and run-off, then recharge of groundwater occurs. The result is excessive deep drainage, which can cause rising or perched saline watertables to appear. Figure 2.10.1 demonstrates how irrigation salinity can occur because of carrying out irrigation or constructing a water storage or supply channel on permeable soil types leading to recharge.

Figure 2.10.1. Schematic representation of irrigation salinity due to permeable soil types



Irrigation salinity occurs in the rice and horticultural areas of the Murrumbidgee and Murray valleys (Australia's oldest irrigation areas) and in cotton areas such as the lower Macquarie, Namoi and Darling river valleys. There is potential for it to become a problem in other cotton-growing areas. In addition, direct application of saline or sodic waters can cause irrigation salinity, since the salts are introduced in the root zone. This is a problem on the Darling Downs and a potential problem in other areas where poor quality groundwater is used.

In order to determine the threat and understand the causes of irrigation salinity, methods and techniques capable of providing this information are required at the field, farm, catchment and regional levels. The identification and measurement of both soil and water salinity are discussed later in this topic.

Cotton and salinity

> *Cotton is more tolerant of salt than most other crops, but salinity problems can easily get to the stage where cotton growth may be retarded. Some of the crops that may have to be grown in rotation with cotton are more sensitive to salt (for example, winter legumes).*

from SOILpak for cotton growers – third edition, C7–1

Cotton is more susceptible to saline scald in early stages of development, a situation compounded by the fact that the highest salt concentrations are found at the top of row crop hills where the crop is planted. Yield decline for adult plants starts at around 7.7 dS/m, with seedlings starting to suffer at around 6.7 dS/m (12% less). A 50 % decline in yield of adult cotton is experienced at levels of 17 dS/m.

Table 2.10.1. Conductivities of saturated extracts and 1:5 soil-water suspensions at which yield decline starts for plants associated with cotton farming systems

Plant salt tolerance	Soil salinity rating	Saturated extract, EC_e (dS/m)	1:5 soil:water suspension, $EC_{1:5}$ (dS/m) Soil texture		
			Silt loam	Medium clay	Heavy clay
Sensitive (e.g. field peas)	Very low	<1.5	<0.16	<0.20	<0.26
Moderately sensitive (e.g. corn, lucerne, broccoli)	Low	1.5–3.0	0.16–0.32	0.20–0.40	0.26–0.52
Moderately tolerant (e.g. cowpea)	Medium	3.0–6.0	0.32–0.64	0.40–0.80	0.52–1.04
Tolerant (e.g. cotton, barley, wheat, sorghum)	High	6.0–10.0	0.64–1.05	0.80–1.33	1.04–1.72
Very tolerant (e.g. saltbush) {halophytes}	Very high	>10.0	>1.05	>1.33	>1.72

Source: modified from *SOILpak for cotton growers*

Field signs of soil salinity are located in SOILpak, section C7-3.

How can we measure salinisation?

On-farm monitoring of salinity levels of both soil and water is easily achieved with commonly available hand-held salinity meters. However, many people have not realised the full potential of these instruments in keeping track of the build-up of salts on the farm and in local waterways.

Salinity meters provide a quick and effective way of monitoring salinity on the farm and in waterways. They are cheap, easy-to-use, and are highly recommended for all irrigators.

The salinity meter is a small and simple battery-powered device that is used to measure the salt content in a solution. This allows a quick and reasonably accurate reading of the amount of salt in water and in soil samples through a simple field test.

By dipping the salinity meter into a solution and measuring the solution's ability to conduct electricity between the electrodes of the meter, you can determine the amount of dissolved salts present. Salts increase the conductivity, so readings increase as salinity levels increase.

The meter then gives a digital readout of the electrical conductivity (EC) of the water, which can be converted to common units of measure for salinity.

Regular testing of water supplies is very important, particularly if bore water is being used for irrigation. Salinity can vary considerably over short periods, and has a profound effect on the growth of plants, especially salt-sensitive varieties.

Table 2.10.2. Common units of measurement for salinity

1 dS/m = 1 mS/cm = 1000 EC (µS/cm) = 640 ppm	So, to convert …		
	From this unit	**To this unit**	**Do this**
1 decisiemen per metre (dS/m)	EC (µS/cm)	dS/m	Divide by 1000
= 1 millisiemen per centimetre (mS/cm)	ppm (mg/L)	dS/m	Divide by 640
= 1000 EC (microsiemens per centimetre)	dS/m	EC	Multiply by 1000
= 640 parts per million in water (mg/L)	dS/m	ppm	Multiply by 640

Soil salinisation

In the past, soil salinity assessment involved observing the soil condition (for example, waterlogging, friable soil structure, bare and salt-encrusted surface soil) or plant growth (for example, poor or stunted growth). Whilst this approach provides an approximation, more information is required. This is because soil salinity may reduce crop yields by as much as 25% without any visible symptoms and so salinity might be well advanced by the time the need for control and amelioration is realised.

There are various methods and techniques that can be used to measure or assist in the assessment of soil salinisation, from laboratory measures to field techniques.

In the laboratory, a number of methods have been developed to prepare soil solutions for EC assessment. In Australia, two methods have been used extensively: a saturated soil paste extract (ECe), and a suspended material preparation ($EC_{1:5}$). The prepared extract, suspension, or other preparation is then measured to determine its electrical conductivity (EC). These are always expressed at a standard temperature of 25°C so comparisons can be made under varying climatic conditions.

How to texture soils and test for salinity

Testing a soil sample is a reliable way to assess how salts are affecting plant growth. Even though it is quicker and easier to test water samples, a soil salinity test shows the soil conditions around plant roots, taking into account the influence of soil texture. Identifying current soil salinity conditions and recording salinity trends will help you recognise and predict soil salinity problems.

To perform the test, samples of soil will be required from the crop root zone. If possible, take a sample from below the root zone as well. Aim to take samples from different soil types in an area using electromagnetic (EM) maps with high and low conductivity areas, aerial photos showing waterlogged and saline areas, cut and fill maps showing saline or sodic subsoils and visual signs such as crop variations and remnant vegetation.

Note that soil salinity will be highest before the rain break or before commencing irrigation, so test soils then. Also note that the test result will be artificially high if gypsum (a calcium salt) has been recently added.

The soil salinity field test

Soil salinity can be measured by a simple field test. The test is reasonably accurate in indicating if salts may cause yield losses or soil management problems, but is not as accurate as laboratory analysis.

Commercial soil tests include salinity as one of the properties tested. The field test for salinity is also called an $EC_{1:5}$ ('EC one-to-five') test because a ratio of 1 part soil sample to 5 parts distilled water is used to find the salinity of the sample.

The three steps in a soil salinity test are:

1. Assess the texture of the soil sample.
2. Measure the salinity of a solution made up of distilled water mixed with the collected soil.
3. Multiply the test result by the conversion factor based on soil texture to get soil salinity (EC_e), which shows how soil salinity will affect plant growth.

In simple terms, a given amount of salt in sandy soils will be more concentrated in its effect on plant roots than an equivalent amount in clay soils. This is because sandy soils hold less water to dilute the salts than clay soils (they have a lower available water content). Find the multiplication factor for your textured soil sample on the conversion factor table (Table 5.3.3).

Table 2.10.3. Coefficients for converting $EC_{1:5}$ (S/m) to an approximate value of EC_e (S/m) based on soil textural properties

Texture class	Textures	Clay (%)	Coefficient
Sands	Sand, loamy sand, clayey sand	<10	-
Sandy loams	Sandy loam, fine sandy loam, light sandy clay loam	10-20	11
Loams	Loam, loam fine sandy, silt loam, sandy clay loam	25	10
Clay loams	Clay loam, silty clay loam, fine sandy clay loam, sandy clay, silty clay, light clay	30-40	9
Light clays	Light clay	35-40	9
Light medium clays	Light medium clay	40-45	8
Medium clays	Medium clay	45-55	7
Heavy clays	Heavy clay	>50	6

Source: after Daniells and Larsen 1991

Water salinity

Surface water tests provide a reading that is accurate only at the time of testing. The salinity can change sharply in a short time due to evaporation or rainfall, so water needs to be tested regularly.

- River water supplies can change, with good quality water often being interspersed with slugs of higher salinity water flowing downstream.
- Groundwater tends to be more constant in the short term. Groundwater should be checked on farm for watertable depth and salinity levels, and more importantly for any changes.

Test wells, observation wells and piezometers are an easy way of measuring the level of the local watertable, and can highlight potential salinity hazards on your property before they become a problem. They measure the free water depth to the local watertable, and give an indication of what is happening to the local watertable.

They are best located:

- in problem drainage areas
- on low parts of the farm
- on light permeable soils (especially areas of prior stream or old watercourses)
- in a non-irrigated areas adjacent to irrigation
- next to large storages and supply channels
- where signs of salting are occurring
- in areas you suspect may have high watertables.

Testing water salinity

Some points to consider when testing water for salinity are:

- Make sure that the water sample is mixed thoroughly prior to testing.
- Rinse the sample container with sample water before collection.
- When sampling from a storage, collect a sample from entry points, and several locations around the storage.
- When sampling from a channel or river, collect a sample from near the middle of the flow and near your pump intake.
- When sampling from a bore, collect a sample from a turbulent area near the discharge pipe, after continuous pumping for at least 30 minutes.
- When testing water from a testwell or piezometer, bail out the water in the pipe and allow fresh groundwater to enter prior to testing.
- Salinity meters should read zero in the air and if not they need to be calibrated.

Crop production can decline if the salts in irrigation water exceed certain levels. It may be difficult to recognise salinity problems in the paddock because there can be a significant yield decline before the signs of salinity are obvious. There may be no obvious plant symptoms or signs of salt on the surface. Some early visible signs for most irrigated plants may be:

- slow or patchy germination and establishment
- stunted growth
- burnt leaf tips. The whole plant may start to lose its vigour and healthy green appearance and appear yellow or bronzed (especially if it is also waterlogged).

In cases where salinity is severe, salt-tolerant plants such as sea barley grass or couch may become more evident.

Table 2.10.4. General water quality benchmarks (in dS/m)

Water type	dS/m
Distilled or rain water	0
Desirable limit for people	0.83
Environmental impacts may occur	1.5
Safe limit for people	1.56
Limit for mixing herbicides	4.7
Seawater	55+

The effects of water salinity on plant yield, where the water of a set salinity level is used for the whole irrigation season, are shown in Table 5.3.5.

Table 2.10.5 Tolerance of crops and pastures to water salinity and root zone soil salinity

Soil type	**Water salinity limits for surface irrigation** (in dS/m)						**Root zone soil salinity** (in dS/m)	
	Well-drained soils		**Moderate to slow draining soils**		**Very slow draining soils**			
Yield reduction	Up to 10%	25%	Up to 10%	25%	Up to 10%	25%	Up to 10%	25%
Pasture legumes								
Strawberry clover	2.1	4.0	1.4	2.6	0.7	1.3	2.1	4.0
Lucerne (most varieties)	2.0	5.4	1.3	3.5	--	--	2.0	5.4
Lucerne (salt tolerant varieties)	3.6	5.9	2.4	3.9	--	--	3.6	5.9
Pasture grasses								
Phalaris	4.2	8.0	2.8	5.3	1.4	2.6	4.2	8.0
Perennial ryegrass	5.6	8.9	3.7	5.8	1.8	2.9	5.6	8.9
Tall wheatgrass	7.5	13.3	5.0	8.8	2.5	4.4	7.5	13.3
Saltbush	12	20	8.0	13	4.0	6.6	12	20
Puccinellia	16	22	10.6	15	5.3	7.3	16	22
Winter crops								
Wheat	6.0	9.5	4.0	6.3	2.0	3.1	6.0	9.5
Canola	6.5	11	4.3	7.3	2.1	3.6	6.5	11
Barley	8.0	13	5.3	8.6	2.6	4.3	8.0	13
Summer crops								
Grain sorghum	1.0	1.5	0.7	1.0	0.3	0.5	1.0	1.5
Maize	1.7	3.8	1.1	2.5	0.6	1.2	1.7	3.8
Soybeans	2.0	2.6	1.3	1.7	0.6	0.8	2.0	2.6
Sunflowers	5.5	6.5	3.6	4.3	--	--	5.5	6.5
Cotton	7.7	12.5	5.1	8.3	2.5	4.2	7.7	12.5

Plants can be watered for short times with saltier water, if fresh irrigation water is available later to flush away the salt and the groundwater is deep enough to allow adequate leaching. Saline water can also be shandied with better quality water to reduce the effects of salts and sodium in irrigation water. However, shandying will diminish the useability of good quality water and should only be used if the quantities of good water far exceed the quantities of poorer quality water. A tool for determining the resultant water quality when mixing different water sources is available on the CottASSIST website.

The values listed in Table 2.10.5 can vary with:

- stage of plant growth: plants are much more susceptible to salinity at germination and seedling stages.
- soil type: influences potential for leaching of salts. If salts cannot leach away from the surface and plant roots it will cause more damage. Water moves through heavier soils (clays) more slowly, so salts in the water are more likely to affect plant growth.

- method of irrigation: spray irrigation concentrates salts and chlorides on leaves and can cause leaf scorching. **Use caution when irrigating with sprays if the water salinity is above low levels.** Leaching of salts is lower under drip irrigation systems but still possible.

Some tips on using saline water

- Use the best quality water when establishing crops, as plants are much more salt sensitive when germinating and when young (especially lucerne and clover).
- The best time to use poorer quality water is in the late summer–autumn period for pre-watering winter crops. Older, well-established plants are more salt tolerant than young plants, winter cereals are more salt tolerant than most other crops and there is less accumulation of salts in the surface soil over the season.
- Avoid filling storages with saline bore water. This water tends to have more salts than channel or freshly recycled water. These salts will build up in time (through evaporation) in the storage, causing the water to become saltier, increasing the leakiness of the storage, and damaging the clay lining. If the bore water is sodic (contains too much sodium), then the clay lining is more likely to slake or disperse: muddying the water in the storage, and possibly breaking down the clay lining and banks.

Management and remediation of irrigation salinity

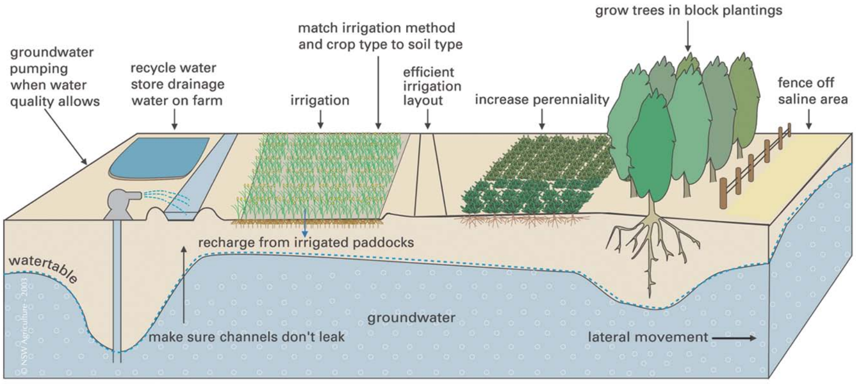
In order to minimise salinity impacts and to improve affected sites, land needs to be managed according to its level of soil salinity. Irrigators need to know their soil types, watertable depths (especially around storages and major supply channels), their current salinity levels for soil and water and the potential risk for further degradation due to salinity.

The land that is most suited to agricultural production has low (0 to 2 dS/m) to moderate (2 to 6 dS/m) levels of root zone salinity. This land has little to no effect on production at the low end and minor yield losses at the high end. This is due to mobilisation of salt into the root zone through capillary rise. There is risk however of further salinisation and visual indications will point to this.

Land that requires protection measures is land with high to extreme levels of root zone salinity, that is, 6 to 15 dS/m and over. Surface salts will affect all plants, and at these levels there is probably a shallow watertable. Change in species composition to highly salt tolerant plants and the appearance of bare patches will be evident. Land at this level of salinisation requires the establishment and maintenance of a perennial groundcover. Irrigated crops can be used to leach away surface salts if there is no shallow groundwater but the land has a high risk of further salinisation. Soils over 15 d/S m are considered extreme, and sites affected have extensive scalding. Most vegetation dies out, leaving only salt-tolerant plants (halophytes). Regeneration of these sites is difficult and requires careful management and protection.

In all cases irrigations need to be scheduled to match plant water requirements at differing stages of the season. The plant requirements continually change due to climatic conditions, rooting depth, stage of growth and are also influenced by soil type. The irrigation water applied should match this crop need in both the amount applied and when it is required. Excess drainage through over-irrigation needs to be prevented if irrigation salinity is to be avoided or reduced in salt prone areas. In areas where it is difficult to manage surface irrigation and its excess drainage, then more precise irrigation methods such as drip and spray could be considered.

Figure 2.10.2. Irrigation salinity management control



Irrigation salinity management control. Source: Southern Salt Action Team 2004.

Irrigation channels and storages should be monitored for leakage. Leaks should be fixed where possible. In worse case scenarios, channels should be re-routed and storages used for short-term storage only, split or even abandoned. Groundwater pumping and subsurface drainage are both methods that are currently used with success to control the impacts of irrigation salinity in some irrigated areas of Australia. At this level of remediation, early prevention is much easier and cheaper.

Early prevention focuses on the correct design of systems, whole farm planning, sound irrigation management, good understanding of the mechanics of salinity and vigilant monitoring for changes in saline conditions.

Irrigators should concentrate their resources such as irrigation water, diesel, seed and fertiliser onto the land suited to agricultural production instead of onto land with higher levels of salinity. Land with low to moderate levels of salinity will give a higher economic return.

On the land best suited to production, ensure that the irrigation-based agricultural systems used maximise the amount of soil water they use, avoid leakage to the watertable beyond the root zone and hence prevent potential salinity problems. Where shallow watertables exist, plant salt-tolerant deep-rooted perennials to draw down the watertable. Also plant trees in targeted areas to intercept lateral groundwater table flows and also draw down shallow watertables.

Land management practices such as effective irrigation management, surface and subsurface drainage, and maintaining groundcover can be used to reduce soil salinity levels. The aim is to maintain soil salinity at a level where agricultural production can occur.

On-farm water quality

Whenever poor quality irrigation water is used, the consequences on cotton crops and soils must be considered. This has become increasingly important in recent years when, for example, drought reduced the availability of good quality irrigation water and many cotton growers reluctantly irrigated with water of poor quality.

Poor quality irrigation water is enriched with salts and nutrients. Consequently its long-term use can cause reductions in cotton growth and soil degradation. These consequences can be minimised or avoided by vigilant crop and soil management, which does, however, involve additional costs. Treated sewage effluent and other industrial waste water which superficially appears to be cheaper than river and bore water has hidden costs in terms of crop and soil management.

Chemically, such water is characterised by high salt (Na and Cl) concentrations and, less commonly, high nitrate and phosphate concentrations, high sodicity, and high alkalinity. Higher concentrations of K are also not unusual. As this water is recirculated, it tends to become turbid faster due to soil dispersion caused by the sodium. The dispersed clay particles in the water also carry adsorbed nutrients and salts. Poor quality irrigation water is commonly bore water, treated sewage effluent or other industrial wastewater, although the quality of recirculated water is also poor as it contains both salts and nitrates picked up as it moves around the farm.

An example of the amounts of salts and nutrients which enter a cotton field in recirculated bore water and treated sewage effluent is given in Table 2.10.6. Assuming uniform concentrations and irrigation efficiencies typical of much of the cotton industry, about 60% to 70% of the salts and nutrients in irrigation water will be retained in the soil.

Table 2.10.6. Quality of treated sewage effluent (Narrabri, NSW) and re-circulated bore water (Merah North, NSW)

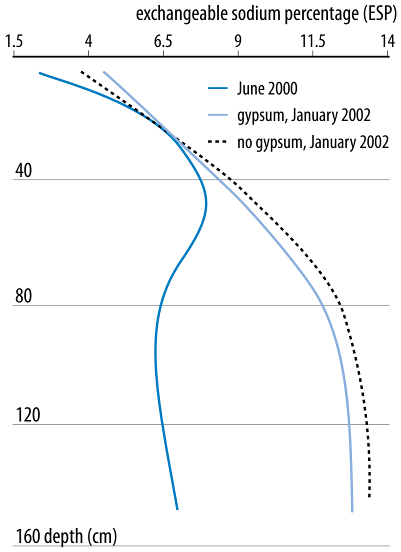
Irrigation date	**pH**	**ECw** dS/cm	**K** kg/ha	**Ca** kg/ha	**Mg** kg/ha	**Na** kg/ha	**Cl** kg/ha	**NO$_3$-N** kg/ha	**SAR**
Treated sewage effluent									
15-Oct-01	8.8	0.71	3.4	13.6	6.4	91.7	843	26.8	5.1
23-Dec-01	8.7	0.69	9.1	11.9	7.2	151.8	858	50.3	8.5
21-Jan-02	8.9	0.73	4.7	8.0	3.7	78.5	977	29.7	5.7
30-Jan-02	8.7	0.71	15.5	13.0	7.7	172.2	1047	46.2	9.3
18-Feb-02	9.2	1.15	8.9	11.2	6.1	119.3	1182	56.6	7.1
8-Mar-02	9.7	1.38	7.7	6.6	5.8	122.7	932	36.8	8.4
Seasonal total			49.2	64.3	36.9	736.2	5840	246.5	
Recirculated bore water									
19-Sep-00	9.1	0.43	2.1	14.1	13.6	54.4	1786	6.0	2.5
6-Oct-00	8.1	0.35	1.6	14.5	8.8	36.6	1626	43.9	1.9
13-Dec-00	8.2	0.52	2.4	12.6	8.2	86.9	1562	15.5	4.7
28-Dec-00	8.1	0.40	2.3	15.1	11.4	59.5	320	57.2	2.8
9-Jan-01	8.2	0.40	1.9	17.0	11.8	56.3	249	4.5	2.6
18-Jan-01	8.2	0.41	2.0	13.8	12.0	68.5	238	2.6	3.2
29-Jan-01	7.8	0.46	2.0	17.0	11.9	72.2	399	31.1	3.3
16-Feb-01	8.2	0.34	2.4	13.1	9.0	41.2	178	37.6	2.1
21-Feb-01	7.7	0.68	3.3	17.1	16.3	94.7	195	16.0	3.9
Seasonal total			20.0	134.3	103.0	570.3	6552	214.4	
River water (Namoi River)									
12-Oct-00	8.7	0.45	5.3	20.4	22.3	41.9	32	29.2	1.5
5-Jan-01	-	0.58	6.6	37.9	21.6	40.0	749	6.8	1.1
19-Jan-01	7.6	0.41	3.7	21.9	18.6	34.9	309	2.8	1.3
Seasonal total			15.6	80.2	62.5	116.8	1090	38.8	
7-Nov-02	8.5	0.27	2.1	15.6	14.2	20.9	249	2.8	0.9
17-Dec-02	8.3	0.25	2.9	11.4	12.3	20.5	245	1.1	1.0
15-Jan-03	8.2	0.28	3.1	16.9	14.6	21.5	199	15.4	0.9
29-Jan-03	8.2	0.21	2.1	13.6	10.3	12.8	167	3.1	0.6
19-Feb-03	8.2	0.27	3.5	12.5	15.6	21.5	217	9.2	1.0
Seasonal total			13.7	70.0	67.0	97.2	1076	31.6	

Notes: Values are an average of 3 fields sampled from the head ditch. For comparison, qualities of river water used at ACRI during the 2000-01 and 2002-03 seasons are also shown.

Nutrient entry to the field (in kg/ha) has been calculated on the basis of an irrigation rate of 1 ML/ha. (EC_w is the electrolytic conductivity of the water, a measure of its salinity, and SAR is the sodium adsorption ratio, a measure of its sodicity. As a general rule of thumb, irrigation water which has $EC_w \leq 0.4$ and SAR ≤ 4 is considered to be good to excellent).

Irrigating with poor quality water, then, can result in soil salinisation, sodification and nutritional stress. Figure 2.10.3 shows an example where soil profile sodification was caused by irrigation with treated sewage effluent.

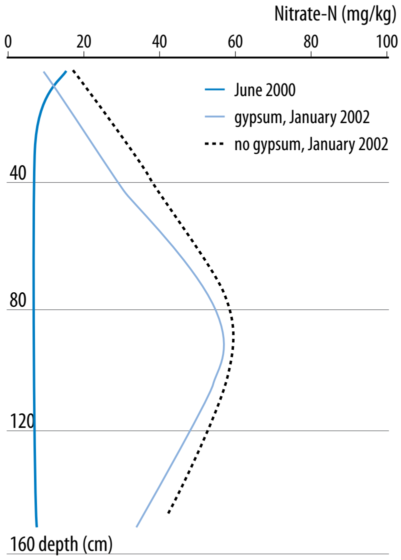
Figure 2.10.3. Effect of gypsum and time on ESP



Note: although gypsum was added, it was not sufficient to prevent sodification.

In addition, excessive amounts of nitrates and phosphates in the irrigation water can move into the watertable and cause pollution of drinking water sources. Figure 2.10.4 shows an example where nitrate in irrigation water (treated sewage effluent) was not used by the cotton crop but has moved deep into the soil profile.

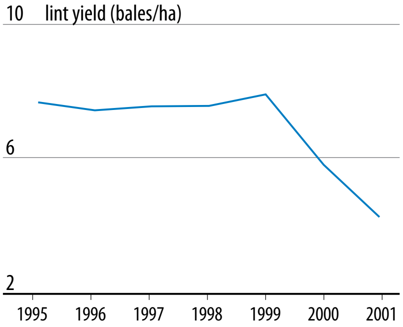
Figure 2.10.4. Effect of gypsum and time on nitrate N concentration



Soil salinisation will result in osmotic (salt-induced water deficiency), nutritional and toxic stresses in crops, whereas sodification causes nutritional stresses, toxicities and soil structural destabilisation. The latter will lead to poor root growth and waterlogging (see SOILPak for more details).

Commonly seen nutritional stresses are K and P deficiencies, and Na and Cl toxicities. Long-term irrigation with poor quality water usually shows up in cotton crops as stunted growth, premature senescence and declining yields (Figure 2.10.5).

Figure 2.10.5. Change in average cotton lint yield at Merah North, 1995-2001. Irrigation water quality deteriorated after 1999



In many fruit crops, Cl toxicity shows up as burns and necrotic lesion on leaves, but in cotton, at the concentrations seen in Australia, Cl toxicity is more likely to be seen as stunted growth due to N deficiency, even though there may be sufficient nitrate-N supplies in the soil. This is because Cl can block uptake of nitrate-N by the cotton crop.

With some sources of poor quality water, such as treated effluent, which has high concentrations of K (for example, about 45 to 60 kg K/ha/season) compared with irrigating with river water (usually less than 10 kg K/ha/season), K deficiency is less likely to occur. P concentration is also high in treated effluent, so P deficiency is also less likely to occur.

Managing poor quality irrigation water

Measure on-farm water quality

Water quality measurements are vital to diagnose issues and determine appropriate management responses. Importantly, regular water quality monitoring may help to proactively identify potential issues before negative consequences occur. As indicated in the case study at the end of this chapter, water quality can vary substantially over time and even between closely located water storages. It is also a Level 2 requirement of myBMP that water quality of all major sources is measured where risks are identified.

Basic water quality testing can be undertaken simply and cost effectively. Salinity meters can be purchased inexpensively and inexpensive test kits for nutrients and pesticides have recently been developed. Further information can be obtained from the Cotton CRC website or the Australian Cotton Water Story (pages 98 and 104).

Avoid irrigating with saline water during periods when cotton is sensitive to salinity

As young cotton between 2 and 10 weeks after sowing is very sensitive to salinity and the mature crop is relatively insensitive, either river or bore water of low salinity or stored rainfall should be the preferred source of water for early season irrigation. Alternatively, 'shandying' of poor and good quality water may be attempted.

As the crop matures and becomes more tolerant of salinity, water of higher salinity can be used for irrigation.

Include a leaching fraction when irrigating

If you are using saline water, a leaching fraction of up to 20% is recommended for most clay soils. This means that an additional amount of water of the order of 20% over that required by the crop is needed to allow the salts which come in with irrigation water to be leached out of the crop's root zone. Consequently water use efficiency of saline water-irrigated crops is lower than when good quality water is used. The disadvantage of using a leaching fraction is that nutrients in irrigation water are also leached out of the root zone.

The leaching requirement to maintain the potential yield for cotton (saturation extract EC = 7.7 dS/m) was measured as part of recent deep drainage trials (see WATERpak Chapter 1.5). This work found that for good quality irrigation water, the required leaching fraction was typically less than one to two per cent. However for poorer quality water (EC = 4.15 dS/m), the required leaching fraction was 12.1 per cent.

The same research also found that whilst there may be some seasons where there was no deep drainage under furrow irrigation, in most cases the average deep drainage was sufficient to satisfy the leaching requirement. However, under CPLM irrigation, a number of seasons of zero drainage were noted, with subsequent build up of soil EC. In such conditions, monitoring of soil EC would be beneficial to ensure that soil EC remains within acceptable limits.

The specific leaching requirement for a given set of crop, soil and water parameters can be calculated using the procedure in the ANZECC Guidelines Volume 1 and Volume 3. Calculations can also be undertaken using tools such as SALFPREDICT.

Manage soil to improve and maintain good soil structure

Good profile soil structure will facilitate leaching of salts which come in with poor quality irrigation water. Management practices which improve soil structure are explained in detail in SOILpak. Briefly, these practices are:

- Using soil amendments such as gypsum, lime or lime/gypsum mixtures, synthetic polymers such as polyacrylamide (PAM), or organic amendments such as composts.
- Using suitable rotation crops to improve subsoil structure. In sodic or saline-sodic soils, rotation crops which are tolerant of sodicity and salinity should be used. Cotton and cereal crops such as wheat, sorghum or forage sorghum can tolerate levels of salinity and sodicity which most grain legumes cannot. Leaching of salt is, therefore, less with most grain legumes. Other crops tolerant of salinity and sodicity are tall wheat and couch grass, barley and Egyptian and Persian clovers. In extreme situations, saltbush and bluebush can be used.
- Minimum ('permanent beds') or zero tillage, particularly when combined with controlled traffic systems, improves soil structure more than conventional tillage systems.

As with using a leaching fraction, the disadvantage of improving soil structure is that nutrients can be potentially leached out of the crop root zone.

Retain salts and nutrients in a 'filtration' field

Saline irrigation water may be passed through a cotton field sown into standing wheat stubble (Figure 2.10.6). As infiltration is higher with standing stubble, salts and nutrients are retained in the field by being moved into the soil profile, and not circulated with recycled irrigation water throughout the entire farm. That is to say, the water which leaves this field is hopefully cleaner than that which entered it (Figure 2.10.7). The salts which were retained in field (Figure 2.10.8) are then leached out of the cotton root zone over time.

Figure 2.10.6. Cotton sown into standing wheat stubble near Narrabri, NSW

Figure 2.10.7. Run-off water from adjacent plots of cotton sown into standing or incorporated wheat stubble (left) standing stubble (right) stubble incorporated

Figure 2.10.8. Exchangeable sodium percentage in adjacent plots of cotton sown into standing or incorporated wheat stubble, November 2001, near Boggabri, NSW

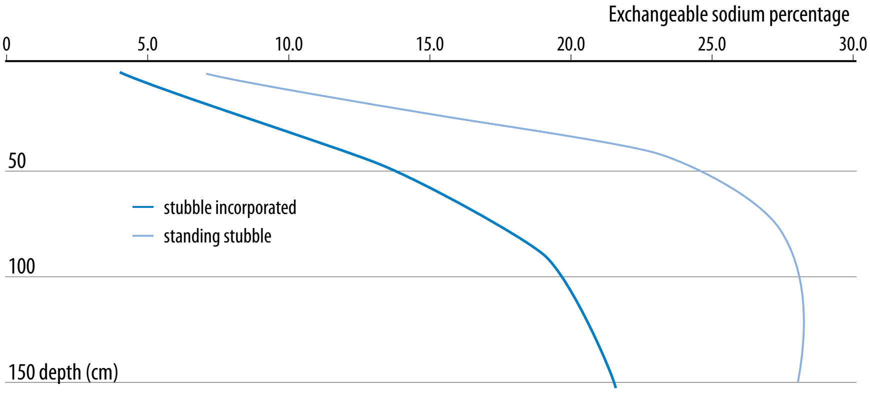


Figure 2.10.9. Clearing standing wheat stubble from furrows with sweeps.

(A) Uncleared furrow with standing stubble , (B) Side view of sweep used in operation,
(C) Standing stubble being cleared from furrow , (D) Cleared furrow with 2-m buffer

It should be noted that furrow irrigation water will be slowed substantially by standing wheat stubble in furrows, resulting in increased infiltration and, in most cases, reduced application efficiency. In addition, some problems can occur, particularly in clay soils, with waterlogging.

This may be overcome by retaining the stubble in the furrows only until the start of the irrigation season. At this point, except for a 1-4 m buffer of standing stubble in the furrows at the tail drain end of the field, the point of a sweep is run through the furrow to clean out the stubble from the bottom 10-cm. This facilitates water flow through the field. The retained buffer is sufficient to slow water flow just enough to sediment out dispersed clay. Excess salts and nutrients adsorbed onto clay particles are deposited in the furrow and do not move off field with runoff. Figure 2.10.9 describes this operation.

Using cereal rotation crops to "sop" up excess nutrients leached out of the cotton root zone

Cereal crops can extract excess nutrients, particularly nitrates, which have been leached below the cotton root zone. The N taken up by the cereals are released on decomposition of the wheat stubble during the following cotton season. Efficiency of N uptake is improved by fertilising the wheat crop, as this improves wheat root growth and allows the root system to extend into the deeper soil horizons (Fig. 8). Figure 8 shows that root density of fertilised wheat is higher than that of either unfertilised wheat or grain legumes. As an example, at the bore-irrigated site described in Table 1 a wheat crop sown after cotton in May 2001 and fertilised with 60 kg N/ha as urea extracted 113 kg of N/ha from the depths below 60 cm. The equivalent fertiliser (anhydrous ammonia) value of this N (assuming a cost of $700/t) was $96.50/ha.

Using constructed wetlands to improve water quality

Recent research has suggested that various water quality parameters may be altered through the design of on-farm water structures. For example, areas of vegetation, particularly in tail drains, can improve sedimentation and microbial breakdown of pesticide residues; but areas of open water are also important for pesticide breakdown by sunlight. A diverse range of structures such as open water storages and purpose built vegetated wetlands may be useful to improve water quality.

When considering these options, growers should be mindful of the effect of vegetation on hydraulic performance, as the capacity and velocity of flow in vegetated taildrains will be considerably less than in clean drains. Similarly, the industry storage guidelines advocate the removal of vegetation from on-farm storages as root activity in storage walls may lead to storage failures. Structures should therefore be designed for purpose, whether this is storing water, transporting water or improving water quality. Further information has been recently published in the Australian Cotton Water Story (page 99).

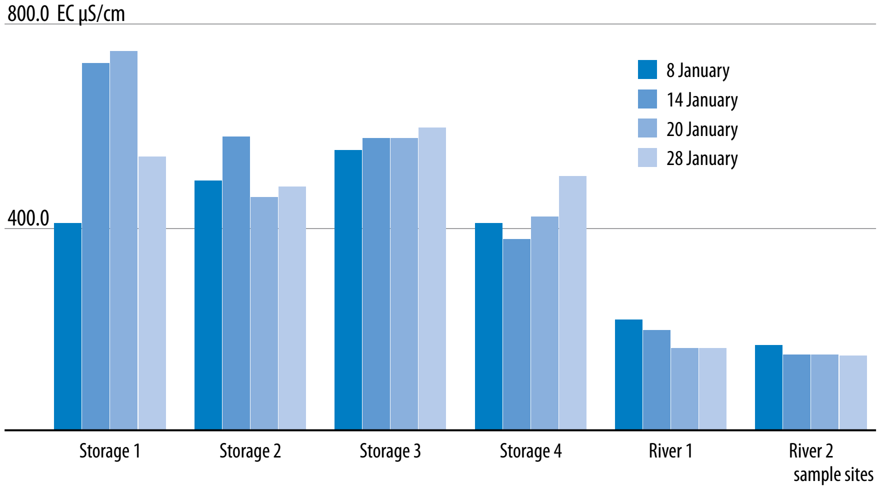
Case Study – Water Quality Monitoring at Dirranbandi

This case study shows the variability detected in water quality over a six week period in the 2001/02 summer at Dirranbandi. Water samples were collected from four on-farm storages (labelled S1 to S4) throughout the Dirranbandi district and from two sites along the Balonne River (labelled R1 and R2), one upstream and one downstream of Dirranbandi. The nutrient and salinity levels of these irrigation water samples were analysed.

Salinity

The salinity level of the Balonne River, measured by electrical conductivity (EC), was much lower than the on-farm storages and remained relatively constant (Figure 2.10.10). The lower electrical conductivity for the river may be explained largely by the fact that EC has a significant negative association with flow. This means that a flow in the river results in the dilution of ions in solution, thus decreasing the EC.

Figure 2.10.10. Electrical conductivity of storage and river water



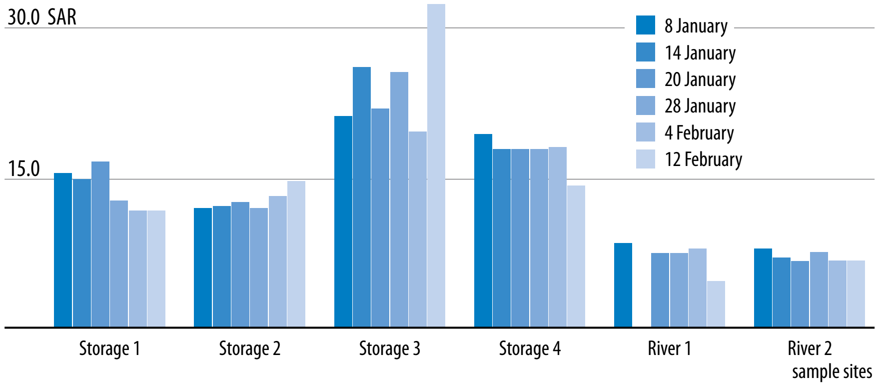
Differences in the storages can be largely explained using recent soil tests from the farm. The sodium and calcium content of the soil on one farm is almost double that of the others. The majority of the samples (91%) were classed as a very low (<650 µS/cm) salinity hazard for irrigation water according to national water quality guidelines, indicating that the water is suitable for irrigation of sensitive crops and will pose no threat to soil salinity.

The average EC of the water in the Balonne River for both sample sites was 170 µS/cm, which is low relative to studies in other cotton-growing valleys that report ECs between 306 µS/cm and 1565 µS/cm in the Liverpool Plains (Wood 1997), 227 µS/cm and 1626 µS/cm in the Gywdir (Montgomery 2002), and up to 800 µS/cm in the Namoi River (DLWC 2001).

Sodicity (Sodium Adsorption Ratio)

The sodium adsorption ratio (SAR) is a measure of the proportion of sodium ions in the soil or water solution, relative to other cations (magnesium, calcium and potassium). The SAR of the river water is much lower than the on-farm water storages. The SAR of the storages varied with 42% of the storages falling in a high sodicity class (8-14) and 58% in a very high sodicity class (>14) (Figure 2.10.11). The difference between the SAR of storages is consistent with the soil test results, which explains why S3 had a much higher SAR value. Irrigating with sodic water will affect soil structure, resulting in soil dispersion and reduced water infiltration.

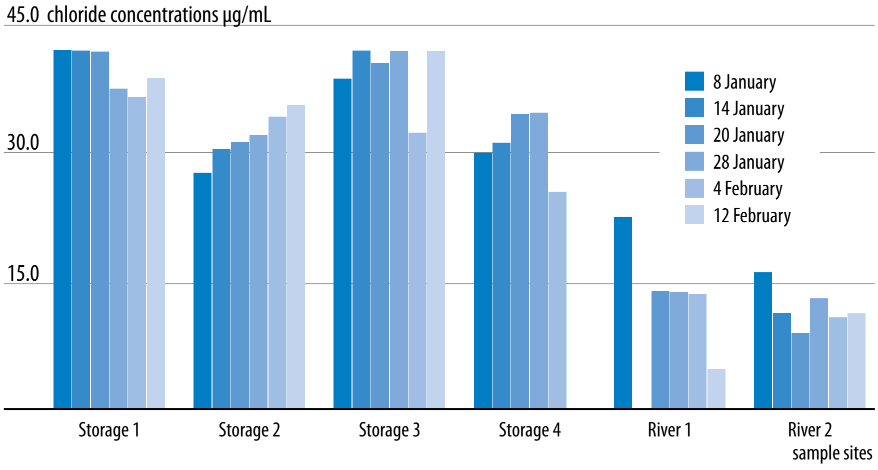
Figure 2.10.11. Sodium adsorption ratios of storage and river water



Chloride load

Chloride is essential for plant growth, although high levels of chloride can cause damage to the crop's foliage and increase the uptake of cadmium from the soil, which can be toxic. All samples had concentrations less than 175 µg/mL (Figure 2.10.12), which indicates that the water is suitable for irrigation of chloride-sensitive crops such as cotton. The chloride level in the river was almost half the values recorded throughout the Gwydir Valley by Janelle Montgomery (2002).

Figure 2.10.12 Chloride levels in storage and river water

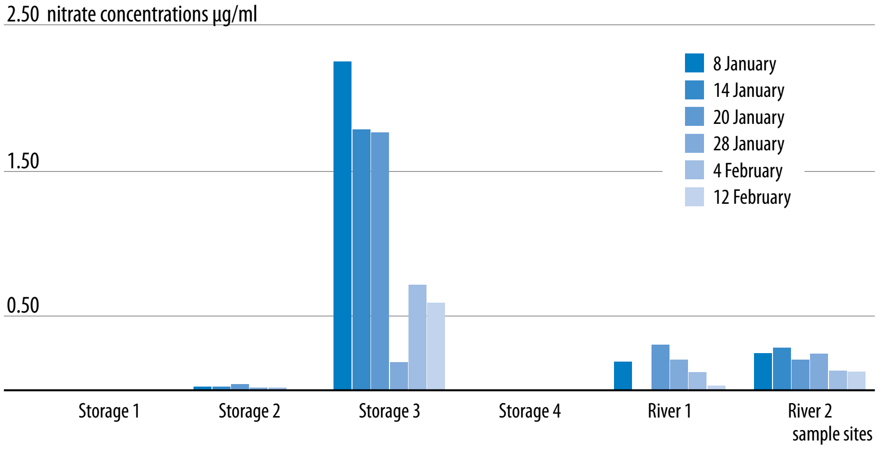


Nitrate load

Nitrate occurs naturally in water and is usually present in river water at concentrations below 1 µg/mL. Levels higher than this are generally related to the use of nitrogen fertiliser, manure, intensive livestock production or urban wastes.

The national guidelines for irrigation water suggest that nitrate levels in irrigation water should be in the range of 25 to 125 µg/mL. During the observation period, nitrate levels were below these levels (Figure 2.10.13). No nitrate was detected in Storage 1 or Storage 4, and only low levels in Storage 2. Storage 3 recorded a much higher nitrate level (2.25 µg/mL), which is a direct consequence of the addition of nitrogen fertiliser to the water prior to sampling.

Figure 2.10.13. Nitrate levels in the storage and river water



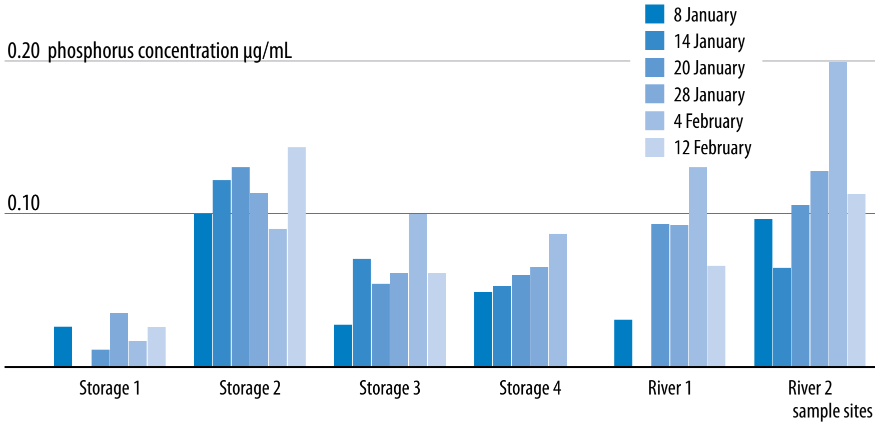
The two river sites recorded maximum nitrate values of approximately 0.3 µg/mL. These levels are similar to those presented from other water quality studies in cotton-growing regions. The majority of samples collected throughout the Gwydir Valley showed nitrate levels between 0 and 1 µg/mL (Montgomery 2002).

Phosphorus

Generally, the concentration of phosphorus in the river water was higher than that in the on-farm storages. This is because phosphorus binds tightly to sediment particles and there are often more sediment particles in river water (Montgomery 2002).

Figure 2.10.14 shows that Storage 1 had the lowest phosphorus concentration, while Storage 2 had the highest concentration. This pattern is consistent with soil test results from these farms. Using a Colwell P soil test, soil P levels of 2 mg/kg were measured on the Storage 1 farm compared to the farms of Storages 2, 3 and 4 which measured 36, 26 and 25 mg P/kg respectively. The levels of phosphorus in the river water increased during the sampling period.

Figure 2.10.14. Phosphorus levels in the storage and river water



High phosphorus levels in water do not generally affect plant growth although, if microbial activity is healthy, they may cause algal growth that may block irrigation equipment (Montgomery 2002). The majority (76%) of the samples from the storages and river exceeded the maximum standard of 0.05 µg/mL for irrigation water that has been set in the ARMCANZ guidelines.

The phosphorus levels in the Balonne River are comparable to other river systems within cotton-growing areas in Northern New South Wales and Queensland. Studies by DLWC have recorded median values of 0.1 µg/mL in the Narrabri Creek at Narrabri and 0.445 µg/mL in the Peel River at the Bective Reserve.

Action

This project highlighted that every on-farm water storage, even those within close proximity of each other, were different in terms of water quality. Monitoring the salinity of storage and river water using an electrical conductivity meter will give you an indication of the level of salinity in the water and any changes that occur over both the short and the long term.

It is very simple and inexpensive to measure the electrical conductivity of a water sample. It costs about $100 to buy your own meter to measure salinity levels.

For more information about monitoring the electrical conductivity or nutrient content of your irrigation water, contact your Cotton CRC Industry Development Officer.

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