# SITE INVESTIGATIONS for URBAN SALINITY

LOCAL GOVERNMENT
SALINITY INITIATIVE



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LAND & WATER CONSERVATION

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# Site Investigations for Urban Salinity - Introduction

## Introduction

It is increasingly recognised that salinity is an issue that needs to be considered when planning urban land use. This booklet provides a  methodology which looks at how to assess and quantify the impact of salinity on a proposed urban development as well as the impact of the development on the salt and water processes. The last step of the methodology is to use the collected information to tailor the design, construction and maintenance of the site to minimise undesirable impacts.

Salinity affected site (photo DLWC SALIVA library)

While salinity should be integrated into natural resource management decision processes, it is presented here as a discrete issue to highlight the ways in which it can affect development and vice versa.

## Salt and it's Effects

Salts in soil come from sources such as:

- weathering of rock and soil
- soils formed on old sea beds
- salt lakes or other saline soils
- the ocean via wind and rain

Surface and ground water can dissolve and mobilise these salts often leading to their accumulation in other areas. Over time a balance is reached between water movement and salt. Ecosystems develop that are adapted to the salt in soil and ground water.

Development can change the movement of surface and ground water thus carrying the salt to other areas. Concentrations of salt and certain kinds of salt can affect plant growth, soil chemistry and structure as well as the lifespan of materials such as bitumen, concrete, masonry and metal. This means that both ecosystems and aspects of any development can be affected. The design of development should keep this in mind.

The processes that move salt through the landscape are a complex interaction between geology, climate, soil, water balance and vegetation. Therefore there is no one prescriptive list of tests to determine the impact of salinity prior to development. Rather any investigation should develop an understanding of processes and interactions peculiar to the site combined with the likely impacts of the proposed development.

Not only can the management, design and construction of the development then take these impacts into account but the new understanding arising from the experience can be used in future investigations and developments.

## Measuring Salinity

Because salt separates into positively and negatively charged ions when dissolved in water, the electrical conductivity of the water increases as the amount of salt increases. To test the electrical conductivity of soil one part of soil is mixed with 5 parts of water. The result is then multiplied by the soil texture conversion factor to give the final figure. This result is known as extract electrical conductivity (ECe) and is given in

Salinity affected site (photo DLWC SALIVA library)

deciSiemens per metre (dS/m).

More information on units of measure and conversion factors are discussed in Appendix 1.

## Saline Soil

A saline soil is defined as a soil that contains sufficient soluble salt to adversely affect plant growth and/or land use.  A soil is often considered saline if it has an ECe of 4 dS/m. This is the level at which many crops are affected.  However more sensitive plants may show effects at 1 or 2 dS/m.  The response is also associated with other factors including pH and the relative amounts of the various cations ( positively charged ions) present in the soil such as sodium, calcium, magnesium and potassium.

The use of an arbitrary ECe reading for determining the impact of salinity on buildings and infrastructure is also an oversimplification.  The impact of salts on building material is related to the amount of salt and water present, the types of salts present, chemical and physical reactions with

Salinity affected site (photo DLWC SALIVA library)

the building materials and the amount of wetting and drying occurring.  This booklet therefore lists a range of possible tests and parameters that can be used to understand the salinity processes on development sites.

## Phases and Scale of Survey

This booklet suggests that a site should be assessed in four phases as follows:

- In the first phase, walk the site and collect any existing information. This will enable you to work out what information is missing and therefore what further tests and research are needed.
- In phase two, conduct a detailed site analysis by methods such as digging soil test pits and installing piezometers.
- The third phase is the laboratory analysis of selected soil and water samples and interpretation of results.
- The fourth phase is selection of appropriate management and evaluation techniques to suit the salt and water processes and the development.

Salinity affected site (photo DLWC SALIVA library)

# PHASE ONE: INITIAL SITE INVESTIGATION AND DESKTOP REVIEW

This phase consists of

- a detailed 'desktop review' of the site and general vicinity,
- an initial site walk.

By collecting as much existing information as possible you can to start to identify the amount and types of salts present, the soil conditions, and the processes that are likely to be happening on the site. This information is used to tailor phase 2 of the site investigation for the development in question, the specific site and the level of current knowledge and understanding. Phase 2 will consist of collecting all the missing pieces to the puzzle, confirming the theories developed in phase 1 .

## Broad scale and Existing Information Sources

There are various information sources that are useful in estimating the amount and type of salts in an area as well as the water movements. For example:

- Climate data such as rainfall and evaporation patterns,
- Landuse and vegetation history,
- Geological maps,
- Urban capability maps and reports,
- Soil landscape maps and derivatives,
- FLAG modelling ( Fuzzy Landscape Analysis Geographical Information System),
- National Dryland Salinity Program tools ( www.ndsp.gov.au) including maps classifying groundwater systems into local, intermediate or regional systems,
- SALIS ( NSW Soil and Landscape Information System),
- DLWC Groundwater database,

(These broad scale investigation tools are further explained in a separate booklet of the Local Government Salinity Initiative package.)

## SALIS

The NSW Soil and Land Information System (SALIS) is a database available from DLWC. It contains soil data from a wide range of sites and sources and is therefore a useful reference point. Site profile information is publicly available and free of charge on the internet (www.spade.dlwc.nsw.gov.au). Consultants requesting bulk data will incur a fee.

DLWC recommends that all soil profile descriptions, gathered as part of an investigation, are recorded on the data cards of SALIS. The cards should then be mailed to:

SALIS Coordinator
Soil and Land Information System
Department of Land and Water Conservation,
Level 4 Macquarie Tower
10 Valentine Avenue (PO Box 3720)
Parramatta 2174

The data can then be entered onto the central database. Credit is given for submitting the cards and this is offset against any cost of obtaining other site profile information held on the system. Soil data cards are available from the SALIS Coordinator at the above address or 'phone: 9895 7988.

## Groundwater Database

DLWC also maintains a state wide groundwater database and provides information from the developing database to the public and to private companies for a fee that covers the time it takes an officer to extract and provide the information. The data available can include bore location, construction details, bore depth, rock/ sediment type, standing water level, yield, salinity etc however the level of information for each bore varies. Requests for raw data should be directed to the Regional Resource Information Manager in each DLWC region. Hydro-geological information may also be obtained from the DLWC regional hydro-geologists.

The Water Management Act requires all groundwater piezometers and bores to be registered with DLWC. In many cases, for example high and low yield bores, a licence is also required prior to construction of the bore. Drillers operating in NSW must also hold a valid driller's licence to help ensure correct construction of bores. Information thus obtained, as well as from other sources is being entered into the groundwater database.

## Defining Landforms

At this stage in the investigation the broad distribution of geomorphic landform units should also be identified for the site. Geomorphic landform units are areas that are characterised by having similar physical and soil forming processes, examples are hill crests, side slopes and foot slopes **(Figure 1)**. Landform will help determine the possible location of salt outbreaks and accumulations in the landscape. These may also be influenced by other geological and structural factors such as dykes and rock bars.

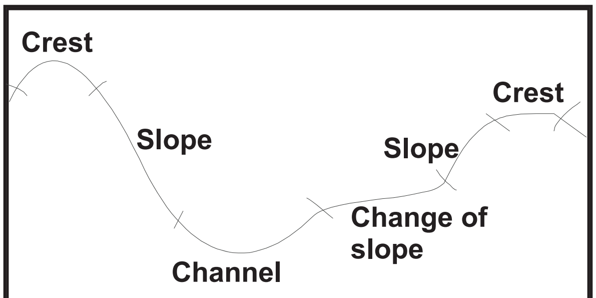



**Fig 1 Examples of landform units**

## Other Information to Collect

Other information collected at this stage should include observations of possible salinity outbreaks and electrical conductivity readings of water bodies such as dams and creeks with a field EC meter.

Indicators of salinity outbreaks on a site include:

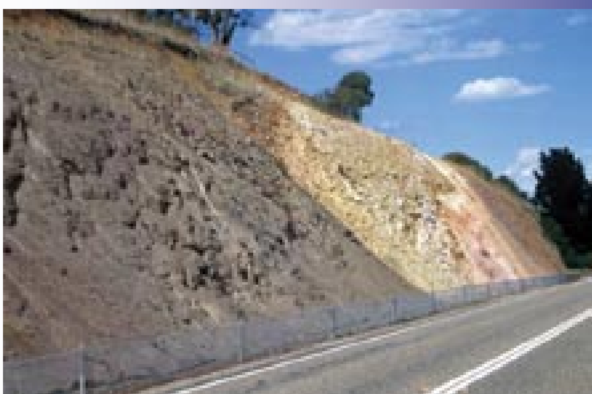
- Bare soil patches,
- Salt crystals present on the surface,
- 'Puffiness' of soil when dry, or greasy, on some soils if wet,
- Black staining on some soils,
- Presence of indicator vegetation species,
- Die back of trees,
- Staining and marking of house foundations.

If salinity is suspected, the soil can be tested using a field meter to measure the conductivity of a 1:5 soil:water extract to confirm the presence of salt. The results will be less accurate than a laboratory test but may help design the in-depth soil survey.

Salinity affected site near residential developement (photo DLWC)

The salinity level of water on the landscape can also be measured, but caution is needed in interpreting the results of tests on water in creeks, seeps of free water in soils etc. As Taylor (1996) points out:

> " A measurement of the electrical conductivity of water, for example in a seepage, bore or stream, is referred to as an EC w. Measuring surface water provides a reference only and indicates that, at a given point in time, a specific location was suffering from the measured degree of salinity.
>
> As massive variations in water quality can occur in the short term, measurements on water samples cannot be used to infer soil salinities at that site for a variety of reasons. These include the levels of water through flow in the soil, the time since rain, the permeability and porosity of the soil, and the position sampled. For example backwater or pools subject to concentration mechanisms such as evaporation often show higher readings than a flowing creek."



Collect local geology and soils information
(photo; DLWC SALIVA library)

## How Many Samples?

Most projects involving intensive development such as urban or industrial projects, require detailed site design and layout and therefore are mapped at a large scale, ie 1:10 000, 1:5 000 or larger. In order to produce a soil map at a similar scale more samples are required than for a development at a smaller scale eg 1:25 000.

The number of samples should enable identification of the soils and landscapes that have different salinity hazards and require different management options. The most intensive land use of the area will also determine the minimum level of testing. Often on a large site there are many different uses and this will mean that different intensities of testing are needed. For example in a site survey for a residential subdivision, open space may be surveyed at a scale of 1:25 000 while residential areas are surveyed at a scale of 1:10 000 or 1:5 000. Table 1 lists typically required scales for different types of development and land use.

Table One also gives a range of samples as a guide for the initial site investigation, phase 1, and detailed site investigation, phase 2. Phase 2 includes soil profile analysis as well as laboratory analysis.

The questions that should be considered when determining which end of the range of samples is appropriate include:

- Do the landscape and soil characteristics vary across the site?
- How much local information about the salt and water processes already exists?
- What is the proposed type of development? For example landuses that don't involve irrigation, effluent disposal, or tree clearing may be less likely to mobilise any salt present and therefore may require fewer investigations.
- What is the cost of sampling relative to the cost of the development? For example $500 worth of soil sampling may not be warranted for a $500 shed, however it may be warranted to determine if a sulphate resistant cement is required for a $150,000 house.
- Are there other types of investigations that could be undertaken? For example an Electro-Magnetic Induction (EMI) survey may be used with only a few soil tests to validate the EMI survey. Alternatively, soil sampling may show there is little salt present but more groundwater information is required because the groundwater is saline, rapidly rising or close to the surface.

| Scale of Mapping | Distance at scale of mapping | Typical Land Use Types | Intial site investigation | Detailed Profile Descriptions | Laboratory Analysis of Soil Profiles |
|---|---|---|---|---|---|
| 1:25 000 | 1 cm = 250 m | Open space | 6-18 per km$^2$ | 1.5-3 per km$^2$ | 0.2-1 per 2 km$^2$ (> 1 per type profile) |
| 1:10 000 | 1 cm = 100 m | Intensive agriculture, low intensity construction | 0.5-1.0 per ha | 10- 20 per km$^2$ | 0.5 –4 per km$^2$ (> 1 per type profile) |
| 1:5 000 | 1 cm = 50 m | Moderately intensive construction, waste and effluent disposal | 2-4 per ha (0.5 – 1 per 0.25 ha) | 0.5-1 per ha | 0.2-1 per 5 ha (> 1 per type profile) |
| 1: 1 000 | 1 cm = 10 m | Highly intensive construction, dams, waste and effluent disposal | 50-100 per ha (0.5 – 1 per 100 m$^2$) | 10-20 per ha | 0.5-4 per ha (>1 per type profile) |

Note: 1 km$^2$ = 100 ha
1 ha = 10 000 m$^2$
Table developed from "Soil and Landscape Issues In Environmental Impact" (DLWC 1997) and Is similar to requirements in "Managing Urban Stormwater Soils And Construction" (Blue Book) Dept of Housing 1998

**Table 1** Recommended Levels of Site Description

# PHASE TWO: DETAILED SITE INVESTIGATION

This phase consists of a detailed site analysis. A soil and groundwater sampling regime should be designed using information from the initial site walk and desktop review. For example how many soil and groundwater samples are needed, where should they be collected from, how should they be analysed. The information collection should be designed to lead to a better understanding of the physical processes operating on the site and to build a picture of the impact of the development on the site and vice versa. If the information collected in phase one shows there is little salt or groundwater hazard or that the processes on the site are already well understood then there will be less work in this second phase.

Outlined below is a list of standard soil and landscape information that should be collected for each soil profile site. Much of this data would normally be collected for geo-technical surveys and in the design of sediment and erosion control plans as described in the "Blue Book" (Dept of Housing 1998). The number of soil profiles required will vary depending on the level of existing information, the scale, intensity and type of the development plus the variability of the landscape. Column 5 of Table 1 provides a recommended range for the number of soil profiles required for a detailed site investigation. Usually there is at least one soil profile for each landform unit. The site profiles selected from the various landform units across the site should form transects. This will enable a three-dimensional picture of the subsoil profiles to be created.

## Landscape Description

### Topography

- Slope gradient and description (eg slope steepness, slope length, waxing, waning, convex, concave ),
- Aspect,
- Elevation,
- Landform pattern ( a general geomorphic description of the area such as plain, low hills, mountains ),
- Landform element (which part of the landform pattern ie crest, mid-slope),
- Landform process (eg, aeolian, alluvial, residual, erosional).

This information is obtained from topographic maps and by site inspection and will give an understanding of the physical processes operating on the site.

### Lithology

- Type of parent material and substrate,
- Degree of weathering.

This analysis can provide information on possible sources of salt and is obtained by site inspection and or from geological maps. Usually the advice of a specialist geologist or soil scientist is required to identify those geological formations most likely to be associated with saline outbreaks. Salt can come from sources other than rocks (eg aeolian dust, ancient sea incursions), so it is necessary to view the complete picture when predicting the potential for the development of salinity. McDonald et al (1990) provides information related to lithology.

### Site Condition

- Ground cover (%),
- Existing degradation (eg erosion, salinity),
- Any indicators of salinity.

This information is obtained by site inspection and air photo interpretation and provides information of the extent of salinity outbreaks at the surface and any other site management problems.

### Hydrology

- Run on and run off details,
- Drainage and permeability,
- Depth to water table (if in the soil profile).

This information is obtained by desktop review and site inspection and provides information on water movement on the site and under the site.

Inspecting the soil (photo; NSW Ag Image Library)

## Soils

All major soil horizons should be described for the following properties:

- Depth of layer and total depth,
- Colour (Munsell - standard method of applying colour to soils) and mottling (yellow and grey blotching indicating periodic water logging),
- Field pH,
- Field texture (relative amounts of clay and sand which indicates how porous the soil will be and how much water it will hold as well as other soil properties),
- Soil water status (how moist the soil is),
- Structure (arrangement of soil particles and size, shape and condition of peds (crumbs) indicates how easily water will move through the soil and likely rooting depth for plants),
- Fabric (appearance of soil using x 10 hand lens),
- Coarse fragments (amount and size),
- Quantity of roots (important for water infiltration into the soil and will give an indication of the rooting depth of soils. Rooting depth is important for predicting the potential for deep drainage),
- Presence of hard pans (hard and often impervious layers that prevent water infiltration and lead to possible water logging).

Survey details such as Map Grid of Australia Reference, location, date, nature of exposure (eg, auger, batter, gully, etc), name of surveyor should also be recorded. McDonald et al (1990) provides information and guidelines on soil descriptions.

The depth to which the soil profile is described should be the greater of the following:

- 3 m or
- distance to solid bedrock (if less than 3 m); or
- depth of potential physical and/or chemical impact from the proposed development (eg depth of disturbance for an underground pipeline).

The depth of 3 m was selected as it is the depth to which a backhoe can reach. A backhoe, in 2002, costs approximately $170 to $200 plus $80 per hour of operation. On average around 1.5 to 2 soil profiles can be described in an hour.

Salinity affected site (photo DLWC SALIVA library)

## Laboratory Analysis

Laboratory analysis of soils should be carried out on carefully selected representative soil profiles to provide a full description of physical and chemical soil properties for each identified landform unit. The number of profiles selected for laboratory analysis should normally be around 5 to 20% of all soil profiles (see Column 6 Table 1).

There should be at least one laboratory analysis conducted for each of the major soil horizons found in each landform unit. If distinct soil horizons are not present then the soils should be sampled at 20 cm, 0.5m, 1.0m, 1.5m, 2.0m, 2.5m and 3.0m. When there is a surface expression of salinity such as salt crystals on the soil, then the top 2cm of soil should be tested separately.

Each sample generally should contain a minimum of 1.5 kg of soil in a cotton bag with clear labelling (giving site number, depth interval, etc), and this should be sent to a laboratory soon after collection. Air-dry soil samples as soon as possible after collection to ensure reliable results from analysis. The “bulking” of topsoil samples is recommended. This is where six or more similar sub-samples within a 10m radius of the soil profile being described are thoroughly mixed together. “Bulking” gives more reliable test results of the topsoil. However, “bulking” **should not** be done for subsoils.

Laboratories often have an accreditation system such as National Association of Testing Authorities (NATA) or to ISO 9000 for the specific test or for the management system of the laboratory. These types of accreditation systems help ensure the reliability of the test results and reports. Full documentation of the sampling and testing methodology, including the equipment and tests used, should be specified in the results sheet. All original laboratory data should be readily available to the consent authority upon request. Where possible, the soil samples should be retained until after the development project has been completed in case further analysis is required.

## Soil Tests for Urban Salinity

The soils tests listed below are divided into two broad categories. The first suite of tests provide information on water movement through the soil and possible impediments to drainage. The second suite helps determine how corrosive soil and groundwater on the development site will be to building materials and infrastructure. The two suites of tests are interrelated as the water movement through the landscape determines where the salts are concentrated and hence the most corrosive.

'Corrosion' here refers to deterioration and removal by chemical attack. In corrosive environments such as areas with saline soil and groundwater, building and infrastructure design, construction and maintenance may need to be modified to ensure the required service life and durability is achieved.

The cost of tests for water movement and corrosivity listed below, in 2002, are around $150 (including GST) per soil sample. If there are no soil horizons present and samples are collected at 20cm, 0.5m, 1.0m, 1.5m, 2.0m, 2.5m, and 3.0m the cost is $1050 (7 x $150) per soil profile. Consider whether this cost is justified in determining the number of soil profiles analysed in this way. Field testing techniques can often be used to estimate if many of these properties require more accurate laboratory analysis.

### Tests for Water Movement

The purpose of this suite of tests is to use measurable indicators to infer how water moves through the soil and landscape. Areas that are likely to concentrate water are also likely to concentrate salts.

**Permeability** - is the rate at which water moves through the soil. Generally, the lower the permeability the more prone the soil can be to water logging. Permeability is determined by various soil properties including texture, structure, compaction, sodicity and presence of impermeable layers or crusts.

**Cation Exchange Capacity (CEC)**- indicates the soil's capacity to store the available positively charged cations such as sodium (Na), calcium (Ca), magnesium (Mg) and potassium (K). It is dependent on the amount and type of clay and organic matter present in the soil. The reason for the inclusion of CEC is that it is required for assessing sodicity.

**Sodicity** - is the level of exchangeable sodium in the soil. It relates to the likely dispersion on wetting and to shrink/swell properties. Sodic soils are prone to:

- very severe surface crusting,
- very low infiltration and hydraulic conductivity,
- very hard dense subsoils,
- severe gully erosion and tunnel erosion,
- restricted root growth and shallow rooting depths for plants.

Hard when dry and slow to wet up, sodic soils are boggy/soft when wet.

Sodicity or exchangeable sodium percentage (ESP) is the amount of exchangeable sodium as a percentage of the CEC

ESP = [Exchangeable sodium / CEC] x 100

Examine the characteristics of the soil profile
(photo; DLWC SALIVA library)

**Dispersibility** - is the susceptibility of soil aggregates to structural breakdown into individual particles. Using the Emmerson Aggregate (Crumb) Test (EAT or ECT) a comparable measure of the susceptibility of soil aggregates to structural breakdown into individual particles in water is determined. Dispersible soils greatly limit water movement through the soil resulting in poor drainage and water logging. There is an Australian Standard for the Emmerson aggregate test, AS 1289.3.8.1 - 1997.

## Tests for Corrosivity

The purpose of this suite of tests is to identify how corrosive an environment is to concrete and steel. The tests are based on Australian Standards 2159: 1995 Piling - Design and Installation. The Standard has two classes of soil conditions:-,

(A) - high permeability soils below groundwater,
(B) - low permeability soils and all soils above groundwater.

In an urban environment additional sources of water, such as leaking pipes and excessive irrigation, can transport and concentrate salt and often cause the groundwater table to rise. Compaction or cut and fill often result in perched water tables creating a secondary groundwater table close to the surface. It could therefore be argued that the precautionary approach would be to use the more conservative classifications listed for soil condition A (see Appendix 2).

The corrosion potential of a soil on concrete is dependent on the level of sulphate, soil pH, and chloride (for reinforcement). It has been noted in AS 2159 that the presence of magnesium and ammonium ions can increase the aggressiveness of sulphate on concrete. This Standard does not quantify this effect, however the German Standard, DIN 4030 Assessment of Water, Soil and Gases for their Aggressiveness on Concrete, includes tests for magnesium and ammonium. Part of the German Standard has been reproduced in Appendix 3. The German Standard should be used as a guide only as German soils, conditions, and building techniques are different to those in Australia.

AS 2159 also gives values for the corrosion potential of an environment on steel based on soil pH, chloride and resistivity. A brief description of each of these factors follows:

**Sulphates** - are negatively charged particles (anions) which are corrosive to building materials, particularly concrete. Sulphates react with the hydrated calcium aluminate in concrete. The products of the reaction have a greater volume than the original material, producing physical stress in the concrete. The concentration of sulphate needs to be expressed as a percentage weight of the soil to be compared directly to AS 2159.

**Soil pH** - measures acidity or alkalinity of a soil and is important in determining the corrosivity of the soil to building materials. Acids combine with the calcium hydroxide component of cement to form soluble calcium compounds. These can be leached from the concrete increasing its porosity and decreasing its strength. (See Australian Standards 1289.4.3.1:1997 Soil Chemical tests - Determination of the pH value of the soil - Electrometric method). The pH will be expressed as pH units and should range between 1.0 (extremely acidic) and 14.0 (extremely alkaline), with 7.0 being neutral.

**Chlorides** - are negatively charged ions (anions) which are corrosive to building material, particularly steels. In concrete, chlorides react with the steel reinforcement causing it to corrode and expand putting physical stress on the concrete. Salt crystals also can cause mechanical damage as they expand in voids in concrete and brickwork. The concentration of chloride should be expressed as parts per million (ppm) or milligrams per litre (mg/L) in water to be compared directly to AS 2159.

**Resistivity** - is a measure of the impedance of electrical current in a soil and is important in determining the corrosiveness of soil on steel. Corrosion in metals involves an electrochemical change of the metal. For corrosion to proceed a medium, the electrolyte, is needed to transfer ions. Resistivity measures the strength of the electrolyte, in this case soil. (See Australian Standards 1289.4.4.1:1997 Soil Chemical tests - Determination of the Electrical Resistivity of a Soils Methods for Sands and Granular Materials). Resistivity should be in measured in ohm.cm to be compared directly to AS 2159.

**Salinity** - though not useful in the assessment of corrosivity provides important information for landscaping. Salinity refers to the presence of excessive salt, which is toxic to most plants. The salt tolerance of plants varies from species to species and stages of growth. Salinity is determined by the electrical conductivity of a soil water extract corrected for texture (see Appendix 1). The two most common laboratory methods are EC (1:2) (one part soil to two parts water) and EC (1:5) (one part soil to five parts water). The different tests will give different EC values that are then converted to ECe using a correction factor of soil texture, so ensure all results are cleared labelled.

## Groundwater Tests for Salinity

Larger projects may require the installation of piezometer(s) to measure the groundwater depth before and after development especially if no data is available in the immediate vicinity of the site. The cost of drilling a groundwater bore in 2002 is approximately $600 to hire the drill rig and $1000 per shallow bore, depending on depth.

Preliminary site and desktop investigations should be used to determine if a piezometer or several piezometers are needed, at what depth and where. The results can help confirm groundwater conceptual models. For example the level of groundwater in a recharge site where water is entering the groundwater system will show more short term response to fluctuations in weather than a discharge point where water is leaving the groundwater system. The chemistry of the groundwater will also reflect the rocks and soil that the groundwater has passed through.

Collect local groundwater information
(photo; DLWC SALIVA library)

There may be several layers of groundwater under a particular site therefore piezometers of different depths may be needed. For example a regional groundwater system where water is entering the ground 50 or 60 km away may be under a local groundwater system where water is entering 1km away. Knowing whether the different systems exist, whether they interact with each other and whether they are rising will help determine if management options are appropriate on the site or elsewhere as well as the type of management option appropriate for the situation.

If a piezometer is installed, observations should be made of the characteristics of each layer in the soil profile as piezometers allow soil measurements and observations to a greater depth than allowable using a backhoe. For example

- Depth,
- ECe
- pH,
- Soil texture and colour,
- Moisture content,

should be recorded for the different soil horizons.

"Specifications and Methods For the Construction of Departmental Groundwater Monitoring Bores in NSW" produced in 1998 by the DLWC Groundwater Drilling Unit in Dubbo is one publication that details construction methods for bores.
Once piezometers are installed a chemical analysis of the groundwater can be undertaken to indicate the likely impact the groundwater may have on the soil, vegetation or man made structures. It is common to test for EC, pH, sodium, calcium, potassium, magnesium, sulphate, carbonates and chlorides. Groundwater chemical analysis will also help determine if the groundwater from different depths and different bores come from a common source or different sources.

Groundwater movement is often complex. Often numerous sources of information over long periods are required to confidently predict processes. Therefore it is important that any site information is compared with any existing information and that new information is recorded in a publicly available database for future use.

Salinity affected site (photo DLWC SALIVA library)

# PHASE THREE: PRESENTATION AND INTERPRETATION OF RESULTS

The third phase of the site investigation involves presenting all the results in a clear and logical manner and comparing the results to various standards, technical manuals and reference documents.

## Presenting the Data

All test results should be clearly presented in tables with the units of measurement clearly shown. Any conversion factors used should also be given as there are often numerous industry standards. This is very important for the correct interpretation and verification of theories relating to what is happening on the site and selection of suitable management options. For example if salinity readings are expressed as EC rather than ECe the result will be underestimated by a factor of 14 for a sandy loam or 6 for a heavy clay. Alternatively EC in decisiemens per metre is a 100 times less than EC in millisiemens per metre but is the same as millisiemens per centimetre.

A map showing the distribution of soil and landform types and soil profile sites over the development site helps relate results to the development layout and visualisation of changes across the site. Soil and landform types that may require different management can then be distinguished. In some cases, consideration could be given to preparing two maps, with one highlighting the main soil landscape units and the other highlighting the areas with similar constraints and management requirements.

The main features that should be included on the site map are:

- soil and landform units,
- drainage lines,
- locations of all site observations, site profile descriptions and analyses,
- legend, scale and north direction.

It is also useful for the map to include topographic contours and vegetation.

The site profile results for the site should be displayed as transects across the site. (see **figure 2** as an example). This will help build up a three dimensional picture of soil and salt distribution in the landscape. It will also assist in assessing the impact the development will have on the salt and water processes of the landscape as well as the impact the landscape may have on the development.

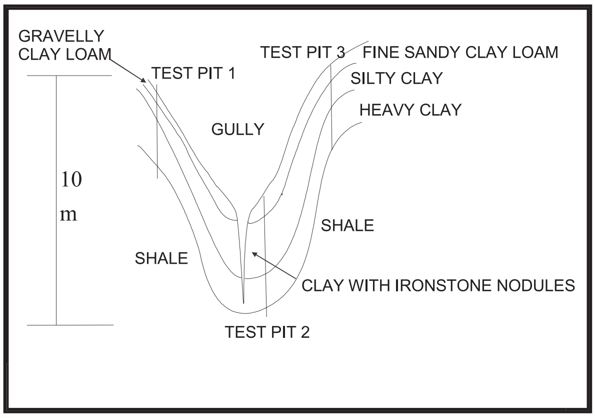



**Fig 2** Example of a soil profile transect

It is useful to present results from the different soil horizons in a soil profile as a graph. For example EC on the X axis and sample depth on the Y axis. A decreasing EC with depth might suggest the soil profile was taken from a discharge site, while a steady low EC might indicate a recharge site. A zone in the profile where EC is higher may indicate the depth of a seasonal watertable or a zone of low permeability.

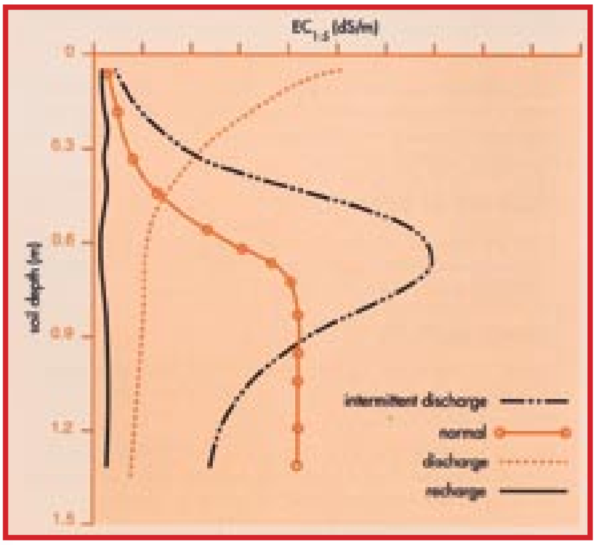



**Figure 3** Typical Salt Profile shapes associated with recharged, discharge , normal and intermittent areas( Qld DNR 1997)

Results should also be assessed relative to what was observed in the field. If a salt scald was observed in the field with salt crystals on the surface then the soil test should indicate high levels of salt. If it does not then there may have been a problem with the labelling of samples, presentation of results etc.

## Interpreting the Data

**Permeability** of soils will determine how quickly and easily rain, applied effluent, irrigation, and contaminants penetrate into the soil profile and possibly raise and/or contaminate the groundwater system.


Salinity affected site (photo NSW Ag Image Library)

Water movement should be considered at several scales. For example the permeability of the various layers of the subsoils can vary. Water flow can therefore be concentrated or confined to particular soil layers. Water movement along these layers is known as through flow or lateral flow. Through flow can be indicated by the soil being paler in colour than the layer above or below. If construction compacts or intercepts this layer, it can interfere with through flow and possibly create a discharge area upslope. This may be at a single house scale, street or suburb scale. On a larger scale groundwater may be moving from recharge areas to discharge areas 1km to over 50km apart.


Salinity affected site (photo DLWC SALIVA library)

An example of types of permeability rates is :

| Texture | Structure | Infiltration | Permeability (mm/h) |
|---|---|---|---|
| Sand | Apedal | Very Rapid | >120 can be measured >250 |
| Sandy Loam | Weekly pedal<br>Apedal | Very rapid<br>Rapid | >120<br>60-120 |
| Loam | Peds evident<br>Weakly pedal<br>Apedal | Rapid<br>Mod. Rapid<br>Mod. rapid | 60-120<br>20-60<br>20-60 |
| Clay Loam | Peds evident<br>Weakly pedal<br>Apedal | Mod. rapid<br>Moderate<br>Slow | 20-60<br>5-20<br>2.5-5 |
| Light clay | Highly pedal<br>Peds evident<br>Weakly pedal | Moderate<br>Slow<br>Very slow | 5-20<br>2.5-5<br><2.5 |
| Medium to heavy clay | Highly pedal<br>Peds evident<br>Weakly pedal | Slow<br>Very slow<br>Very slow | 2.5-20*<br><2.5<br><2.5 |
| Clay | Sodic and saline<br>Sodic<br>Highly sodic | Moderate<br>Very slow<br>Extreme | 8.0<br><2.5<br><1.0 |

* Strongly structured polyhedral subsoils e.g. Krasnozem

**Sodicity** is expressed as the amount of exchangeable sodium as a percentage of the Cation Exchange Capacity or ESP %. Various ranges are used to rank ESP % as non sodic, sodic or highly sodic. One example is:

| ESP % | Rating |
|---|---|
| < 5 | Non-sodic |
| 5-15 | Sodic |
| > 15 | Highly sodic |

When wet, sodic soils lose their structure and disperse into very small particles, the small particles fill the pore spaces in the soil effectively blocking them. This impermeable layer can severely impede water movement.

The depth and thickness of the layer of sodic material will determine the effect on development. For example a thin sodic layer deep in the soil profile may not cause a problem if the surface layers of soil are not removed and infiltration of water or effluent is designed to suit the site conditions. Excessive water entering the profile may be prevented from draining further by the sodic layer and result in tunnelling soil erosion. Gullying or tunnelling can be an issue if the sodic subsoil is exposed to rainfall, or construction leads to an outlet developing for water ponded above a sodic layer. With a sodic layer at the surface however, erosion is an issue. Plants may have problems establishing if erosion has removed the nutrients and the sodic crust is preventing air and water entering the soil profile. Stability for structures may also be an issue especially if the layer is thick.

Calcium, mostly in the form of gypsum, is often added to sodic soil to address the balance between sodium and calcium in the soil.

**Dispersibility** of soils is not always related to sodicity. Soils with poor soil structure, low amounts of organic matter and low sodium levels can also be highly dispersive. The sugars in the organic matter help bind soil together.

The Emmerson Aggregate Test can be used to rank soil dispersibility into classes from 1 to 8. Air dried soil is placed in water. As the water is absorbed air becomes trapped within some pores spaces. The pressure of this air can be enough in some soils to make it disperse. This type of dispersion is called slaking and refers to Emmerson aggregate classes 1 to 6. Those soils that don't slake are put into classes depending on whether they swell (class 7) or not (class 8).

Once the soil is immersed in water, dispersion can continue due to the stresses between the charged particles present. If these charged particles are readily dissolvable within water eg sodium or there is a large total number of salts present then dispersion will be greater. The reactions are used to classify soils into class 1 to 6. Class 1 and 2 soils can result in tunnelling erosion. Class 3 are stable and don't leak if compacted when wet. Class 4,5 and 6 however are highly aggregated materials and are less likely to hold water even when compacted.

Dispersible soils should be taken into account in the design of sediment and erosion control plans but also in terms of water and salt movements in the landscape. Dispersible soils can be managed by maintaining vegetation cover and possibly adding organic matter, gypsum and lime depending on the Emmerson aggregate class result.

Salinity affected site (photo DLWC SALIVA library)

**Corrosivity** test results can be compared with such sources as:

- AS 2159 (1995) Piling -Design and Installation. Extracts of this are given in Appendix Two.
- The German Standard DIN 4030 Assessment of Water, Soil and Gases for their Aggressiveness to Concrete. An extract of this is given in Appendix Three.
- The manufacturers specifications for various products and materials.

By understanding the salt and water processes on the site the likelihood of changes over time to results of testing can be estimated. In some cases the site may need to be managed carefully to ensure a particular outcome. The management options chosen may vary across the site. Ongoing monitoring of the site may also be necessary to determine success.

# PHASE FOUR: MANAGEMENT AND EVALUATION

In the final report, the results presented in phase three need to be interpreted in terms of the current conditions on the site and what is likely to occur in the future.  This latter component can only be undertaken if there has been sufficient investigation (phase one and two) to obtain an adequate understanding of the processes occurring on the site and in the area.  Soil sampling alone might show that there is little salt present on the site.  However, mobilisation and concentration of this small amount of salt may lead to salinity issues in the future.  Alternatively, there may be a saline groundwater under the site that is intercepted by plant roots or deep constructions, or the groundwater may be rising to the surface due to offsite causes.

Urban developement encroaching on agricultural land
(photo NSW Ag Image Library)

The issue of cumulative impacts should also be addressed.  Lots of small changes brought about by numerous developments can result in a significant impact in the longer term.  Often simple management options and a precautionary approach can limit these cumulative impacts.  This is usually more cost effective than trying to address a problem after it has occurred.

Questions that should be considered in phase four include:

- **How will the proposed development alter the above ground and below ground water movement on the site as well as the salt store?**

  Particular consideration should be given to:
  • water sensitive urban design principles of infiltrating surface water into the ground,
  • the use of stormwater detention ponds and wetlands,
  • the watering of lawns in residences and open space,
  • cut and fill techniques of construction,
  • compacting and disturbing soils in road and building construction,
  • the building of service trenches,
  • exposure of saline or sodic soils.

- **What will be the impact of the altered water and salt movement on the development and environment, on and off site, if left unmanaged ?**

  Particular attention should be given to:
  • the change in concentrations of salts, particularly chloride and sulphate ions, that can have a corrosive effect on construction materials of roads and buildings,
  • capillary action drawing water and salt upwards,
  • wetting and drying effects on soil and building materials concentrating salts,
  • AS 2159 Supp 1 -1996 Piling - Design and installation - Guidelines Section 4 and AS 3600 Supp1 -1994 Concrete Structures Commentary Section C4 for additional information on designing for durability,
  • The effect of change in water movement and salt on flora, fauna and water quality.  Impact on flora in particular may have a compounding effect. Death or removal of deep rooted, perennial vegetation may lead to lower rates of removal of groundwater by transpiration and thus a rise in the groundwater level.

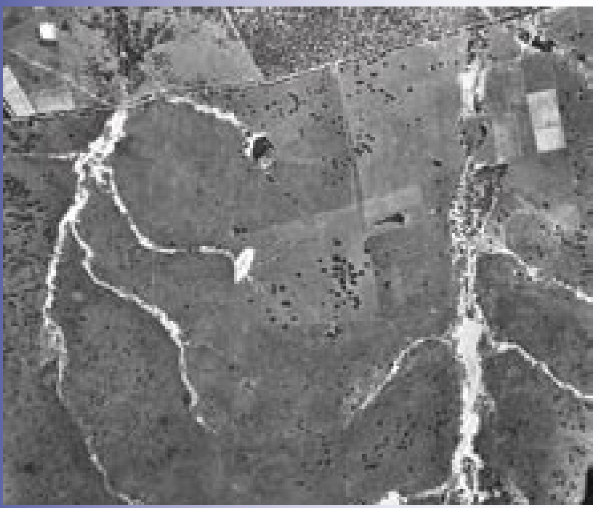
- **What management options and strategies are proposed to mitigate the effects of altered water and salt movement?**

  To minimise the impact of the development on the water and salt processes on the site, possible management options might include:
  • minimising water infiltration,
  • the use of landscaping using native plants,
  • sealing stormwater detention ponds,
  • retention of deep rooted vegetation,
  • minimising soil disturbance such as compaction and cut and fill.

To minimise the impact of the water and salt processes on the development, possible management options may include:-

- careful installation of damp proof courses,
- water proofing the slab,
- good site drainage,
- the use of higher strength concrete with thicker cover and exposure class masonry,

(These building issues are further explained in a separate booklet of the Local Government Salinity Initiative package.)



Aerial photo showing salinity indicators
(Land Property Information)

Aerial photo showing salinity affected in rural areas
(Land Property Information)

Alternatively management could also be tailored to the particular soil and water processes of different parts of the site. Appropriate management options for recharge areas include:-

- Minimising infiltration of stormwater,
- Minimising on site sewer disposal,
- Use of local provenance native vegetation in landscaping to minimise the need for irrigation,
- Lawns linked to moisture probes and only watered to match the plants requirements,
- Planting of deep rooted native trees to increase water use,
- Retaining native vegetation where possible,
- Stormwater detention ponds and water features lined to reduce infiltration.

Urban developement encroaching on agricultural land
(photo NSW Ag Image Library)

Appropriate management options for areas with shallow water tables are the same as for recharge areas in conjunction with:-

- Damp proof courses correctly installed and maintained in buildings,
- Well drained building sites,
- Utility trenches designed so they do not concentrate saline groundwater flow,
- Minimised disturbance of drainage lines,
- Minimised cut and fill so saline or sodic subsoils are not exposed or groundwater intercepted,
- Soils replaced in their original order if excavations are undertaken,
- Sediment and erosion control plans that take into account saline and sodic soils.

Management options for permanent, periodic or historical discharge sites could include:-

- Use of appropriate construction materials and techniques to salt proof buildings and infrastructure,
- Use of salt tolerant vegetation in landscaping,
- Treating sodic soils with gypsum before landscaping,
- Rehabilitating salt scalds,
- Drainage and treatment of the collected salt water,

- Use of pier and beam construction. This has several advantages over slab construction namely;-
    - Allowing evaporation to occur at the soil surface,
    - Limiting the amount of building material in contact with salt or water,
    - Allowing any damage to be more easily observed,
    - Limiting the need for cut and fill and thus exposure of sodic or highly saline subsoil or disturbance to natural drainage.

Salinity affected site (photo DLWC SALIVA library)

- ***What degree of certainty is there that the proposed strategies will mitigate the effects of altered water and salt movement?***

A monitoring and evaluation system should be developed for the site, which is appropriate for the degree of certainty and the possible ramifications if they are wrong. For example, during construction evidence of localised perched water tables and unexpected changes in soil characteristics should be noted and taken into consideration. If piezometers have been installed to gain an understanding of the processes on the site these should continue to be monitored. Often groundwater movement is very slow so that the impacts of the development or remedial measures will not be apparent for numerous years. Care should therefore be taken to place peizometers where they can remain during and after development.

Salinity affected site (photo DLWC SALIVA library)

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## APPENDIX ONE: UNITS USED TO EXPRESS SALINITY

From Taylor (1996) pages 9,10 and 25

### Units Used to Express Salinity

The Department of Conservation and Land Management has adopted the Australian Laboratory Handbook of Soil and Water Chemical Methods (Rayment & Higginson 1992) standard of dS/m (deciSiemens per metre) as the unit of measurement of electrical conductivity and, hence, salinity. This is an inferred measure of the amount of salt in water or in a soil:water suspension. This measurement does not account for the effects of different ions in the solution.

Many other departments and private consultants use a number of different measures for various reasons including historical precedents, compatibility with international groups or simply personal preference. For example, the Western Australian Department of Agriculture commonly uses units of ppm (parts per million).

Measurement of the individual ionic components in a solution is generally in mmol/L (millimols per litre). Measurement of soluble salts in a soil may be expressed in terms of mg/kg (milligrams per kilogram).

A range of conversions between different units of electrical conductivity and other parameters follows. The measure of mol/L (moles of salt per litre) has been left out due to the lack of common use outside the ranks of soil chemists and technicians and because of the extra complications of using differing molecular weights and involved formulae.

### MEASUREMENT CONVERSIONS TO DECISIEMENS PER METRE (dS/m)

- **dS/m = mmho/cm = mS/cm**
  (deciSiemens per metre = millimhos per centimetre and milliSiemens per centimetre)
- **dS/m x 100 = mS/m**
  (deciSiemens per metre by 100 = milliSiemens per metre)
- **dS/m x 1 000 = µS/cm**
  (deciSiemens per metre by 1000 = microSiemens per centimetre; µS/cm is a widely used measure in water samples and is commonly called an "EC Unit")
- **dS/m x 640 = ppm = mg/L = µg/ml** (approximately)
  (deciSiemens per metre by 640 = parts per million AND milligrams per litre AND micrograms per millilitre. These express total dissolved salts)
  **Note:** The conversion from dS/m to ppm can vary markedly depending on the salts present. To highlight this, for each of the single salt solutions shown, an EC of **1 dS/m** at 25°C is equal to the following concentrations in parts per million (mg/L):

| | |
|---|---|
| $MgCl_2$ | 400ppm |
| $CaCl_2$ | 465 |
| NaCl | 500 |
| $Na_2SO_4$ | 630 |
| $MgSO_4$ | 710 |
| $CaSO_4$ | 800 |
| $NaHCO_3$ | 970 |

(Source: Richards, 1954)

The figure of 640 is used as an accepted average.

- **dS/m x – 0.36 = OP** in bars (OP = osmotic potential), multiply bars by 100 for kilopascals (kPa)
- **dS/m x 10.96 = meq/L of NaCl** (milliequivalents per litre of *sodium chloride* – varies with type of salt)

### Other Conversions

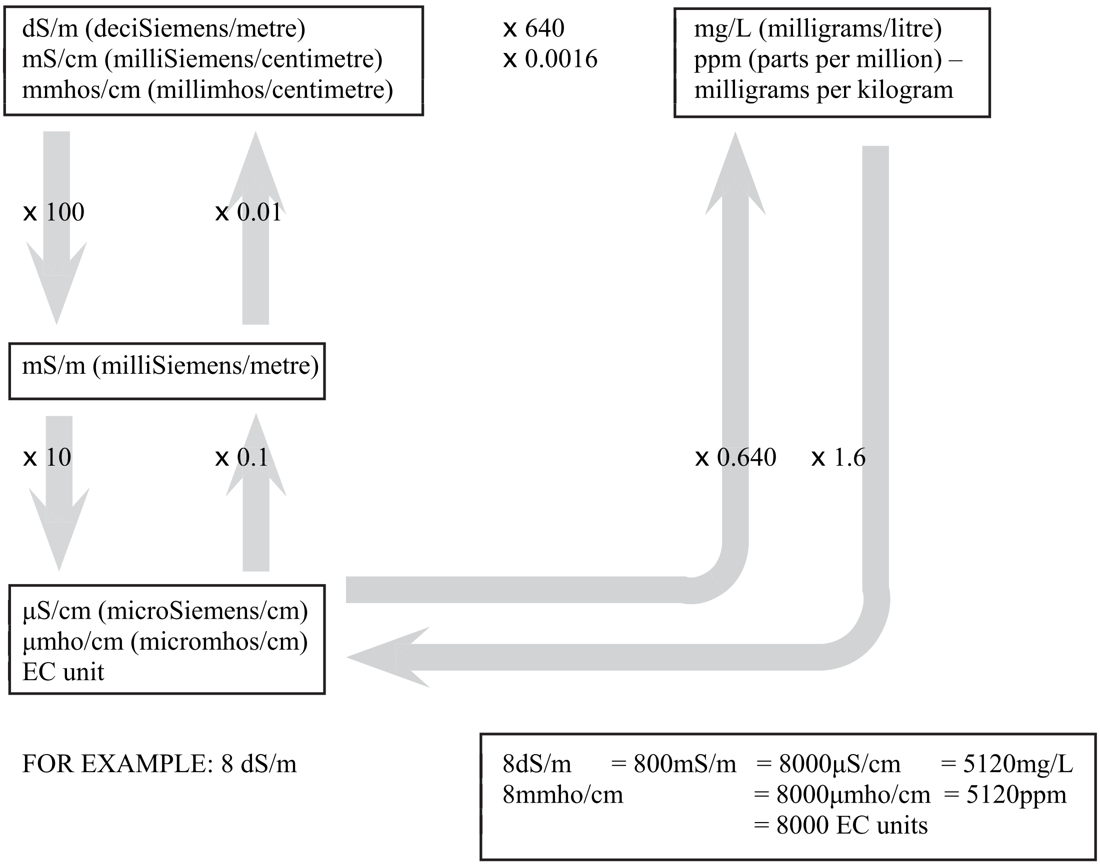
- **EC 1:5 (dS/m) x 0.34 = total soluble salts (TSS) as g/100g of soil (%)**
  ( % TSS estimated from the EC in d/Sm of a 1:5 suspension at 25°C )
  this assumes salt content at 640 mg/L, (for NaCl assume 500 mg/L and use 0.25)
- **mhos/cm = 1 000 x mmhos/cm** (dS/m)
  (mhos per centimetre = 1 000 millimhos per centimetre (or dS/m)
- **mmhos/cm = 1 000 x µmhos/cm**
  (millihos per centimetre = 1 000 micromhos per centimetre)
- **µmhos/cm = µS/cm**
  (micromhos per centimetre = microSiemens per centimetre)

The following older measures may still be referred to by some clients. They are inserted here due to several requests of extension staff.

- **grains per imperial gallon[1] = 14.28 ppm**
  (a measure previously used and still referred to by some landholders, it is weight of salt in grains, remaining after evaporation of all water in one imperial gallon)
- **grains per US gallon[2] = 17.10 ppm**
  (as above but for the US gallon)

Many conversions are factors of ten. Parts per million (which equals mg/L etc.), and osmotic potential are the main exceptions. For quick reference, Figure 3.1 which depicts the more common measures and their conversions has been included.

**FIGURE 3.1 – COMMON EC MEASUREMENT CONVERSIONS**




Source: Adapted from B. G. Williams and B. Wild (pers comm)

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[1] **4.546 litres = 1 imperial gallon**
[2] **3.785 litres = 1 US gallon**

**TABLE 6.1 FACTORS FOR CONVERTING EC (1:5) TO ECe**

| Soil Texture Group[8] | Multiplication Factors[9] |
|---|---|
| **Sands** have very little or no coherence and cannot be rolled into a stable ball. Individual sand grains adhere to the fingers. | 17[10] |
| **Sandy loams** have some coherence and can be rolled into a stable ball but not to a thread. Sand grains can be felt during manipulation. | 14 |
| **Loams** can be rolled into a thick thread, but this will break up before it is 3-4 mm thick. The soil ball is easy to manipulate and has a smooth spongy feel with no obvious sandiness. | 10 |
| **Clay Loam** can be easily rolled to a thread 3-4 mm thick but will have a number of fractures along its length. The soil is becoming plastic, capable of being moulded into a stable shape. | 9 |
| **Light clays** can be rolled to a thread 3-4 mm thick without fracture. Plastic behaviour evident, smooth feel with some resistance to rolling out. | 8.5 |
| **Light medium clay** is plastic and smooth to the touch and will form a ribbon of 7.5cm. | 8 |
| **Medium clay** handles like plasticine, forms rods without fracture, has some resistance to ribboning shear, ribbons to 7.5cm or more. | 7 |
| **Heavy clays** can be rolled to a thread 3-4 mm thick and formed into a ring in the palm of the hand without fracture. They are smooth and very plastic with a moderate to strong resistance to rolling out. | 6 |

Source: Multiple sources (see below)

**TABLE 6.2: ECe VALUES OF SOIL SALINITY CLASSES**

| Class | ECe (dS/m) | Comments |
|---|---|---|
| Non – saline | <2 | Salinity effects mostly negligible |
| Slightly saline | 2-4 | Yields of very sensitive crops may be affected |
| Moderately saline | 4-8 | Yields of many crops affected |
| Very Saline | 8-16 | Only tolerant crops yield satisfactorily |
| Highly saline | >16 | Only a few very tolerant crops yield satisfactorily |

Source: Richards, (1954)

**WATER SAMPLES**

A measurement of the electrical conductivity of water, for example in a seepage, bore or stream, is referred to as an ECw. Measuring surface water provides a reference only and indicates that, at a given point in time, a specific location was suffering from the measured degree of salinity.

As massive variations in water quality can occur in the short term, measurements on water samples cannot be used to infer soil salinities at that site for a variety of reasons. These include the levels of water throughflow in the soil, the time since rain, the permeability and porosity of the soil, and the position sampled. For example, still backwaters or pools subject to concentration mechanisms such as evaporation often show higher readings than a flowing creek.

It has been suggested that there is a relationship between the electrical conductivity measured in water, the ECw, and the electrical conductivity of the soil, the ECe, under irrigation. When dealing with dryland salinity however, any relationship is determined by many factors. Water salinity is of interest for other reasons such as quality for drinking, irrigation and stock use (Figure 6.3).

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[8] Soils are classified for texture on the degree to which moist soil can be rolled out in the palm of the hand. Take a small quantity of soil and knead with water until a homogeneous ball is obtained. Remove large pieces of grit and organic matter. Small clay peds should be crushed and worked in with the rest of the soil. The feel, behaviour and resistance of the soil to the manipulation during this process is important. Keep the soil ball moist so that it just fails to stick to the fingers. See Northcote (1979) for more complete soil texture information. Texture groups from: - Soil Conservation Service - Riverina, "Instructions for use of TPS conductivity meter and guidelines for interpretation of salinity values." (undated field guide)

[9] Unless indicated otherwise, these conversion factors are estimates derived from testing of soils by soil chemists from the NSW Department of Agriculture. Factors vary within broad bands for each texture unit and have been interpreted to derive the factors shown. (P. Slavich, pers. comm.)

[10] Yo and Shaw (1990)

## APPENDIX TWO:
## EXTRACT FROM AUSTRALIAN STANDARDS 2159 – 2009 PILING – DESIGN AND INSTALLATION

AS 2159-1995 has been reviewed and is superseded by AS 2159-2009. Any reference to AS 2159-1995 in the text of this document should now be referred to AS 2159-2009.

The Tables related to this Appendix are extracts from AS 2159 – 2009 Piling – Design and Installation and are found in AS 2159 – 2009, Section 6, Durability Design between pages 38 and 46. These Tables should be used in conjunction with the associated text and Notes of Section 6 (Parts 6.1 to 6.6) to ensure Durability Design criteria are assessed within the intended context.

The printed hard copies of this Appendix contain reproductions of Tables 6.4.2 (A), Tables 6.4.2 (B), Tables 6.4.2 (C) with Notes, Tables 6.4.3 with Notes, Tables 6.5.2 (A), Tables 6.5.2 (B), Tables 6.5.2 (C) with Notes, and Tables 6.5.3 with Notes from AS 2159 – 2009 Piling – Design and Installation. Reproduced with permission from SAI Global under licence 1005-c012-3.

Salinity affected site (photo DLWC SALIVA library)

Salinity affected site (photo DLWC SALIVA library)

# APPENDIX THREE: EXTRACT FROM GERMAN STANDARD DIN 4030 CORROSIVITY ASSESSMENT FOR CONCRETE

| Parameter Checked | Degree of Aggressiveness | | |
|---|---|---|---|
| | **Low** | **High** | **Extremely High** |
| pH Value | 6.5 to 5.5 | Below 5.5 up tp 4.5 | Lees than 4.5 |
| Carbonic acid ($CO_2$) in mg/L (heyer marble test) | 15 to 40 | Over 40 up to 100 | Over 100 |
| Ammonium ($NH_4^+$) (mg/L) | 15 to 30 | Over 40 up to 100 | Over 100 |
| Magnesium ($Mg^{2+}$) (mg/L) | 300 to 1000 | Over 1000 up to 3000 | Over 3000 |
| Sulphate ($SO_4^{2-}$) (mg/L) | 200 to 600 | Over 600 up to 3000 | Over 3000 |

**Table 4:** Limiting values for assessing the degree of aggressiveness of water of mainly natural origin

Salinity affected site (photo DLWC)

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