SOUTH AUSTRALIAN WATER CORPORATION

TG 10k

# TECHNICAL GUIDELINE

# GENERAL TECHNICAL INFORMATION FOR GEOTECHNICAL DESIGN

## ~ Part K ~
## Geotechnical Si Units System

Issued by: Manager Engineering

Issue Date: 10 January 2007

Government of South Australia

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# No Changes Required In the January 2007 Edition

The following lists the major changes to the December 2004 edition of TG 10k:

1. Nil

# Contents



# Tables & Figures

# Referenced Documents

**AS 1000** The International System of Units (SI) and Its Application

**AS 1686** Metric Units for Use in Sewerage and Drainage (Including Plumbing

# Section 1: Scope

# Section 2: Guidelines For The Expression of SI Units and Their Symbols Within SA Water

## 2.1 A LITTLE HISTORY

The International System of Units (SI) is the most simple, rational, coherent, clear and universally accepted system of measurement ever devised by civilised man. The USA has not adopted it as yet. The British, who began their changeover in 1968, are still working out a way to blend the new, rather "French", system with the old Imperial system so as not to inconvenience or confuse anyone, and to retain the quaintness of their country road signs - after all, an English mile will always be an English mile. Australia made a crisp, well managed, no-problems changeover in about a three month period during 1972. The EWS had significant input to the execution of the changeover nationally as well as running its own internal program. For many years SI has been the only system of "weights and measures" legally permitted for use in Australia.

**Might You Still Be Incorrectly Expressing SI Units and Their Symbols?**

Do you, for example, mix words and symbols in unit names, e.g. km/hour instead of km/h; use the wrong symbols, e.g. Km (kelvin metre?!) instead of km for kilometre; slip in non-preferred units such as centimetres; use ugly and unnecessary abbreviations like "sec" or "ltr"; add a totally taboo "s" or full stop after a unit symbol, e.g. "kms" (kilometre second?!); do you put more than one slash in a compound unit symbol, e.g. t/d/km instead of t/d.km (pronounced tonnes per day kilometre) - mathematically the first way puts the km up top with the tonnes - to see how ridiculous it is try using several "/"s with molar entropy, whose symbol is $kg.m^2/s^2.K.mol$, or try putting a second per in "dollars per man day"; or do you commit any of the dozens (sorry, tens) of other common errors?

## 2.2 SI AND SA WATER PREFERENCES

The guidelines are based on Australian Standard AS 1000 -1979 *(The International System of Units (SI) and Its Application*), and also AS 1686 -1974 *(Metric Units for Use in Sewerage and Drainage (Including Plumbing))*.

They are intended to fill the need for a concise, "everyone-has-a-copy-on-their-desk" reference on the use of the SI. In addition to indicating the way things should be done in general, the guidelines help in the selection of those units or presentation methods preferred for SA Water use *where AS 1000* ***permits*** *a choice*. For example we use / for "per" not negative indices, hence t/d.km in preference to $t.d^{-1}.km^{-1}$ (the latter is tricky to type, often hard to print and unfamiliar to many). We are also comfortable with megalitres and gigalitres for large volumes of water instead of cubic metres.

**Section 1** sets out the basic rules for expressing units, and lists the more commonly used units of SI, the version shown being that preferred for use in SA Water.
**Section 2** addresses the use of electrical conductivity units for water salinity measurement.

This "Technical Note" was prepared by Ed Collingham, 14/12/1997
(Ex Principal Engineer Geotechnical)

# Section 3: CLAUSE ON USE OF SI

All calculations, drawings, reports, specifications, tender documents and manuals shall be in SI units in accordance with AS 1000–1979 (The International System of Units (SI) and its Application). Attention is drawn to Sections 8 and 9 of AS 1000, which deal with the expression of numerical values, unit names and unit symbols, in particular the requirement to leave a space between the numerical value and unit symbol (eg 100 mm not 100mm). The symbol to be used for litre is capital L.

## 3.1 NOTES TO USERS OF THE CLAUSE

1. The above clause is intentionally specific in an attempt to counter the sloppy practise prevalent in the media and unfortunately also in some technical publications. It is recommended that it be reproduced in full until things improve.

2. The reasons behind the SI rule requiring a space to be left between the number and the unit symbol are legibility and clarity. Few would consider joining a number and a unit name eg 11metres versus 11 metres – it would be both unnecessary and confusing. Because of their brevity, it is even more important to have a space before a unit symbol – particularly with symbols such as the tonne (t), lumen (lm) and lux (lx) in some fonts. Eg in Arial: 11lm versus 11 lm, and in Times New Roman: 11 m versus 11 lm. If there is a concern about the symbol wrapping at the end of a line then use a hard space (Shift+Cntrl+SpaceBar) instead of a normal "soft" space.

3. The SI symbol for litre is L. In an unusual lapse of its commendable rationality and simplicity, AS 1000 states in Table 7 Note 2 that "The symbol l is permitted, but should not be used where it is likely to be confused with the figure 1. e.g. in l/s." As there are almost no occasions when 1 would not be confused with l e.g. 11 l versus 11 L, then SA Water has elected to use only the preferred symbol, L, for litre.

This "Technical Note" was prepared by Ed Collingham, 30/11/2000
(Ex Principal Engineer Geotechnical)

# Section 4: Water Salinity Measurement

## 4.1 WHAT IS THE SALINITY OF WATER?

The **salinity** of water is the concentration of all the dissolved salts in it. The concentration is usually expressed in units of **milligrams per litre** (mg/L) with the suffix TDS to indicate "Total Dissolved Salts". For example: 1 500 mg/L TDS.

A total dissolved salts determination can be made either by evaporating water and weighing the residue, or by adding up the ionic concentrations determined by other methods. Both approaches require laboratory facilities and are fairly expensive.

Fortunately, there is a good correlation between total dissolved salts and the much more easily and cheaply measured parameter of **electric conductivity**. The electric conductivity of a water sample is therefore often measured instead of the actual total dissolved salts.

The use of electric conductivity as an indirect, but convenient, way of gauging the salt content of water is so common, that "salinity" is often reported directly in units of electric conductivity (always measured at or corrected to 25°C). No attempt is made to convert to total dissolved salts.

## 4.2 WHAT IS THE UNIT OF ELECTRIC CONDUCTIVITY?

The SI unit for electric conductivity is **siemens per metre** (S/m). The appropriate SI sub-multiple for use in the water industry when referring to the salinity of water is the **millisiemens per metre** (mS/m). This sub-multiple will give numerical values of the order of 30 mS/m for tap water, and 3 000 mS/m for saline groundwater.

## 4.3 WHAT OTHER ELECTRIC CONDUCTIVITY UNITS WERE OR ARE USED?

The **micromho per centimetre** (μ[mho]/cm) was the most common "old metric system" unit for electric conductivity. With the introduction of SI, this was soft-converted to **microsiemens per centimetre** (μS/cm). Tap water is about 300 μS/cm and saline groundwater about 30 000 μS/cm.

*(Note: Although one mho is equal to one siemens, the soft conversion to microsiemens per centimetre breaks three general SI rules for the expression of units and symbols detailed in AS 1000. These rules are: (a) Multiples or sub-multiples should not be used in the denominator of a unit. (b) Only one multiple or sub-multiple should be used to form a unit. (c) Although centimetres are a permitted for general use, it was intended that they be reserved for use in the clothing industry and the home, and **not** used in technical work.)*

As a compromise, **decisiemens per metre** (dS/m) was adopted in some areas. Note that 1 dS/m is equal to 1000 μS/cm. Tap water is about 0.3 dS/m and saline groundwater about 30 dS/m.

*(Note: While there are no sub-multiples in the denominator,* dS/m *still breaks the SI rule that deci is not a preferred sub-multiple in technical work.)*

Agricultural scientists measure the electric conductivity of **saturated soil extracts** ($EC_e$), and also the electric conductivity of **1:5 soil water suspensions** ($EC_{1:5}$). The results may be found quoted in any unit, although **decisiemens per metre** (dS/m) is becoming the international norm in the agricultural science community and has even been adopted in their Australian Standards.

*(Note: The argument given for the retention of the soft-conversion* μS/cm *for general use, and for* dS/m *by the agricultural science community, is that people have become accustomed the numerical values they give, and should not be asked to change (to the Si unit of millisiemens per metre). Fortunately the same argument did not ultimately succeed in preventing the adoption of decimal coinage and SI in most parts of the world.)*

## 4.4 SA WATER POLICY ON ELECTRIC CONDUCTIVITY UNITS FOR SALINITY

The present policy within SA Water and the Australian Water Quality Centre, is to continue to use the old microsiemens per centimetre (μS/cm) – for reasons of familiarity, consistency of data and because this is what most conductivity meters read in. **So, where salinity is to be quoted in terms of electric conductivity, the unit used should be:**

**microsiemens per centimetre μS/cm**

**(1) The term "EC unit" should be avoided.**

*(Note: EC unit is only an acronym for electric conductivity unit and so gives no indication which electric conductivity unit it refers to. In SA Water we would normally assume* μS/cm*, but outsiders may not. Its use should be restricted to conversation, and even there the full phrase "EC unit" used to emphasise it is an acronym. In SI, the symbol* EC *means exacoulomb [$10^{18}$ coulomb] – a very large electric charge.)*

**(2) If converting to TDS**, indicate that the result was derived from an "electric conductivity" or "EC" measurement. **Eg: 30 000 mg/L TDS (by EC)**

**(3) Conversions** can be tricky, so quote the **# …. #** line below anywhere it might be helpful.

## 4.5 CONVERSION BETWEEN ELECTRIC CONDUCTIVITY UNITS

**1 dS/m** = **1 mS/cm** = 100 mS/m = 1000 μS/cm

**1 mS/m** = 0.01 mS/cm = 0.01 dS/m = 10 μS/cm

\# **1 μS/cm** = 0.001 mS/cm = 0.001 dS/m = 0.1 mS/m #

## 4.6 CONVERSION FROM ELECTRIC CONDUCTIVITY UNITS TO TDS

**dS/m** to mg/L TDS multiply by **600** (550 below 4 dS/m rising to 660 by 50 dS/m)

**mS/m** to mg/L TDS multiply by **6** (5.5 below 400 mS/m rising to 6.6 by 5 000 mS/m)

**μS/cm** to mg/L TDS multiply by **0.6** (0.55 below 4 000 μS/cm rising to 0.66 by 50 000 μS/cm)

**"x" μS/cm** = $(0.548x + 2.2*10^{-6}x^2 - 2.06*10^{-12}x^3)$ mg/L TDS

*(Notes: The formula was derived by Peter Deland of the State Water Laboratories. It is accurate to +/- 5% up to* 70 000 μS/cm*, and then too high. All of the above conversions are applicable only to waters with the typical ionic mix found in South Australian river and groundwater.)*

## 4.7 CORRECTION OF ELECTRIC CONDUCTIVITY READING TO 25°C

Table 4.1 - Correction of Electric Conductivity Reading to 25oC.

| Water Temperature °C | Multiply Reading by | Water Temperature °C | Multiply Reading by |
|---|---|---|---|
| 10 – 12 | 1.4 | 23 – 27 | 1.0 |
| 13 – 15 | 1.3 | 28 – 33 | 0.9 |
| 16 – 18 | 1.2 | 34 – 40 | 0.8 |
| 19 – 22 | 1.1 | Note: the conductivity of water is always quoted at 25°C | |

This "Technical Note" was prepared by Ed Collingham, 20/01/2000
(Ex Principal Engineer Geotechnical)

# Section 5: Some Commonly Used SI and Non-SI Units and Selected Multiples and Submultiples

Table 5.1 - Some Commonly Used SI and Non SI Units and Selected Multiples and Submultiples

| UNIT | UNIT NAME | $10^{-6}$ micro μ | $10^{-3}$ milli m | UNIT SYMBOL | $10^{3}$ kilo k | $10^{6}$ mega M | $10^{9}$ giga G |
|---|---|---|---|---|---|---|---|
| length | metre | μm | mm | m | km | 1 000 km (Mm not used) | 1 000 000 km (Gm not used) |
| mass | kilogram (base unit) | mg | g | kg (base unit) | t (tonne) (1000 kg) | kt | Mt |
| time | second | μs | ms | s (not sec) | min (minute) / h (hour) (not hr) / d (day) (not day) | | a (year) (not yr) |
| area | square metre | - | $mm^2$ ($10^{-6}$ $m^2$) | $m^2$ | $km^2$ ($10^6$ $m^2$) | ha (hectare) (not Ha) ($10^4$ $m^2$ or 100 m x 100 m or 0.01 $km^2$) | |
| solid volume | cubic metre | - | $mm^3$ ($10^{-9}$ $m^3$) | $m^3$ | $km^3$ ($10^9$ $m^3$) | - | - |
| liquid volume | litre | - | mL | L (not lower-case l) | kL ($m^3$) | ML | GL |
| velocity | metre per second | - | mm/s | m/s | km/s | km/h (not km/hr or kph) | |
| force | newton ($kg.m/s^2$) | - | - | N | kN | MN | - |
| mass density | kilogram per cubic metre | $mg/m^3$ | $g/m^3$ | $kg/m^3$ | $t/m^3$ | - | - |
| pressure stress | pascal ($N/m^2$) | - | mPa | Pa | kPa | MPa | GPa |
| flow | litre per second | - | mL/s | L/s | kL/s ($m^3/s$) | ML/s | ML/d GL/a |

*Note: Cells with double lines around them do not fit the column headings.*

### The Expression of Numbers and the Writing of Unit Names and Symbols in SI

1. **SI is the International System of Units. Its application in Australia is detailed in AS 1000X1979.**
   - Sections 1 to 7 of AS 1000 define and explain base units, supplementary units, derived units and non-SI units.
   - Section 8 of AS 1000 gives the rules for expressing numbers in SI (aspects of which are discussed in the notes below).
   - Section 9 of AS 1000 gives the rules for writing unit names and symbols in SI (aspects of which are discussed in the notes below).
   - Section 10 of AS 1000 (the Annex) lists all units and common multiples and sub-multiples.

2. **SI symbols are <u>not</u> abbreviations, they are internationally recognised and fixed symbols.** Any abbreviations will read as something else or as nonsense, eg: ms means milliseconds not metres, KGS reads as "kelvin giga siemens" not kilograms.

3. **A space is <u>always</u> left between the number and the unit symbol.** Eg: 100 mm <u>never</u> 100mm or 11 L <u>never</u> 11L (For a hard space that will not wrap at the end of a line or column use Shift+Ctrl+SpaceBar instead of SpaceBar.)

4. **The decimal marker is a point on the line.** Eg: 21.67 – never a mid-height point or, in SA Water, a comma – see note (10).

5. **The symbol for " per " is a forward slash " / ".** Negative indices are equally correct in SI, but we have elected not to use them in SA Water, so "per square metre" should be $/m^2$ not $m^{-2}$. By the rules of maths only one "per" symbol can appear in a compound unit.

6. **Use all words or all symbols.** Eg: either km/h or kilometres per hour never km per h or kilometres/h.

7. **Never use full stops after symbols (except at the end of a sentence).** Symbols are not abbreviations – see (2) above.

8. **Unit names are given a plural " s " if appropriate, but unit symbols are not.** (Eg: 10 kilometres is OK but 10 kms is not.)

9. **Break long numbers into groups of three figures separated by spaces, counting outwards in both directions from the decimal point.** (Eg: 100 000.000 01) This rule can be waived in text (but not usually in tables) provided there are only four figures before and/or after the decimal point, in which case they may be kept together. (Eg: 4000 or 0.0004 or 1234.5678).

10. **Never use commas instead of spaces between groups of three figures.** They are unnecessary, add clutter, reduce clarity, and may be misinterpreted as a decimal marker. (Many other countries use the comma as the decimal marker in their legal version of SI.)

This "Technical Note" was prepared by Ed Collingham, 20/10/2002
(Ex Principal Engineer Geotechnical)

# Section 6: Some specialist Used SI and Non-SI Units and Selected Multiples and Submultiples

Table 6.1 - Some specialist Used SI and Non-SI Units and Selected Multiples and Submultiples.

| UNIT | UNIT NAME | $10^{-6}$ micro μ | $10^{-3}$ milli m | UNIT SYMBOL | $10^{3}$ kilo k | $10^{6}$ mega M | $10^{9}$ giga G |
|---|---|---|---|---|---|---|---|
| torque | newton metre | torque is force multiplied by lever arm | - | N.m | kN.m | MN.m | - |
| energy or work | joule | work is force x distance moved 1 J = 1 N.m | mJ | J | kJ | MJ | GJ |
| power | watt | power is the rate of doing work 1 W = 1 J/s | mW | W | kW | MW | GW |
| consumption of electric energy | watt hour | 1 watt hour = 3.6 kJ (ie 1 joule per second x 3600 seconds) | | W.h | kW.h | MW.h | GW.h |
| electric potential | volt | μV | mV | V | kV | MV | - |
| electric current | ampere | μA | mA | A | kA | MA | - |
| electric charge | coulomb | 1 coulomb = 1 ampere second A.s | mC | C | kC | The ampere hour ( A.h ) may be used for storage batteries. 1 A.h = 3.6 kC | |
| electric capacitance | farad | μF | mF | F | - | - | - |
| electric resistance | ohm | μΩ | mΩ | Ω | kΩ | MΩ | GΩ |
| electric conductance | siemens | μS | mS | S | kS | - | - |
| electric conductivity | siemens per metre | μS/m | mS/m | S/m | kS/m | For water "salinity" the μS/cm and the dS/m are in common use – See Note 5 | |

*Cells with double lines around them are comments and do not fit the column headings.*

**Some Other SI and Non-SI Units and Notes on the Application of the System**

**(1) Temperature:** SI unit: kelvin ( K )
Other unit: degree Celsius ( °C ) Conversion: °C = K – 273.15

**(2) Frequency:** hertz ( Hz ) multiples: kHz MHz GHz

**(3) Rotational frequency:**
revolution per second ( r/s ) revolution per minute ( r/min )

**(4) Marine and air navigation:**

1 nautical mile ( n mile ) = 1852 m
1 knot ( kn ) = 1.852 km/h = 0.514 m/s

**(5) Salinity.** The salinity of water is the concentration of salts dissolved in it, usually expressed in milligrams per litre with the suffix TDS for "total dissolved salts". Eg: 850 mg/L TDS. For any given mix of salts there is a correlation between TDS and electric conductivity. Because electric conductivity is easy to measure it is commonly done instead of a gravimetric assay, and "salinity" is often quoted in electric conductivity units

("EC units") without conversion to gravimetric units. The appropriate SI unit for "salinity" would be the millisiemens per metre (mS/m). Unfortunately some old metric units are still in common use in salinity work. In recognition of this situation, and with apologies to other SI purists, the following conversions between unit systems are given:

| | | | | |
|---|---|---|---|---|
| **1 dS/m** | = 1 mS/cm | = 100 mS/m | = | 1000 μS/cm |
| **1 mS/m** | = 0.01 mS/cm | = 0.01 dS/m | = | 10 μS/cm |
| **1 μS/cm** | = 0.001 mS/cm | = 0.001 dS/m | = | 0.1 mS/m |

The State Water Laboratories have indicated that South Australian surface and groundwaters are reasonably consistent in the mix of salts they contain, and that a single correlation can usually be applied to them all, as follows:

| | | |
|---|---|---|
| **dS/m** to mg/L TDS | multiply by 600 | 550 below 4 dS/m rising to 660 by 50 dS/m |
| **mS/m** to mg/L TDS | multiply by 6 | 5.5 below 400 mS/m rising to 6.6 by 5 000 mS/m |
| **μS/cm** to mg/L TDS | multiply by 0.6 | 0.55 below 4000 μS/cm rising to 0.66 by 50 000 μS/cm |

Or apply the formula

**"x" μS/cm** = $(0.548\mathbf{x} + 2.2*10^{-6}\mathbf{x^2} - 2.06*10^{-12}\mathbf{x^3})$ **mg/L TDS**

(reliable up to about 70 000 mg/L)

**(6) Mass density and "unit weight".** Mass density is the amount of mass (ie matter) in unit volume of a substance. It is an intrinsic property of the substance that applies in all places at all times – unlike the old, confusing, imperial concept of "unit weight" (eg "kN/m"), which is redundant and does not exist in SI. If gravity is acting on a mass to produce a force which is relevant in a given calculation, then "g" ( 9.81 $m/s^2$ ) appears in the calculation (force = mass x acceleration). If gravity forces are not relevant, "g" does not appear.

This "Technical Note" was prepared by Ed Collingham, 21/10/2002
(Ex Principal Engineer Geotechnical)