Engineering

Technical Guideline TG0635

General Technical Information for Geotechnical Design - Permeability

Version: 2.0
Date: 25 October 2019
Status: ISSUED

Document ID: SAWG-ENG-0635

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Government of South Australia

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Significant/Major Changes Incorporated in This Edition

This is the first issue of this Technical Guideline under the new numbering format. The original version of the document was last published in 2007 with the name of General Technical Information for Geotechnical Design Part H – Permeability (TG 10h). A full version history of this document is given in Document Controls. The major changes in this revision include the following items:

- Major revision of Section 3 (formerly Section 5 in TG 10h), with addition of definitions, methods of determination, and minor revision of typical values
- Minor revision of Section 4 (formerly Section 2 in TG 10h)
- Minor revision of Section 5 (formerly Section 3 in TG 10h)
- Section 4 of TG 10h in not included in TG 0635.

Document Controls

Revision History

Revision	Date	Author	Comments
0	2004	Ed Collingham	First Issue of TG 10h
1	10/1/2007		Nil
2	25/10/2019	Moji Kan	Major Revision, Reformatting to TG 0635

Template: Technical Guideline Version 6.00, 10/05/2016

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Contents

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1 Introduction

SA Water is responsible for operation and maintenance of an extensive amount of engineering infrastructure.

This guideline has been developed to assist in the design, maintenance, construction, and management of this infrastructure.

1.1 Purpose

The purpose of this guideline is to detail minimum requirements to ensure that assets covered by the scope of this guideline are constructed and maintained to consistent standards and attain the required asset life.

1.2 Glossary

The following glossary items are used in this document:

Term	Description
SA Water	South Australian Water Corporation
TG	SA Water Technical Guideline
TS	SA Water Technical Standard

1.3 References

1.3.1 Australian and International

The following table identifies Australian and International standards and other similar documents referenced in this document:

Number	Title
NA	

1.3.2 SA Water Documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Number	Title
TS 4	Packing Sand (Pipe Embedment and Trench Fill Sand)

1.4 Definitions

The following definitions are applicable to this document:

Term	Description
SA Water's Representative	The SA Water representative with delegated authority under a Contract or engagement, including (as applicable): • Superintendent's Representative (e.g. AS 4300 & AS 2124 etc.) • SA Water Project Manager • SA Water nominated contact person
Responsible Discipline Lead	The engineering discipline expert responsible for TG 0635 defined on page 3 (via SA Water's Representative)

2 Scope

The scope of this document is to provide guidelines on selection of the soil permeability values for the design of SA Water infrastructure.

3 Definitions, determination and typical permeability values

The permeability of a soil is the ability of water to move through it (permeate it). It depends on the physical and chemical properties of the soil, notably particle size distribution (the range of particle sizes present), pore space, pore size and the continuity of the spaces.

The soil permeability refers to the ability of a soil to conduct water. Hydraulic conductivity, or *k*, reflects how far water will move through soil in a given time. Hydraulic conductivity is a complex feature of soils, varying with location, soil type, depth, soil moisture content and direction of flow; for example, horizontal conductivity is often greater than vertical on account of soil horizons.

It is expected that in design of SA Water infrastructures, if coefficient of permeability or hydraulic conductivity is needed, appropriate laboratory or field tests be conducted to determine required permeability values. Some test methods that might be requested by the geotechnical engineer are discussed in following sections.

3.1 Prediction methods

a. **Particle size analysis** can be used to predict the hydraulic conductivity of unstructured sands and sandy loams. This relies on equations that take values measured in the lab. On the other hand, it is not suitable for well-structured soils, especially clays, as structure can make a clay act more like a gravel.

b. **Permeability class** can be estimated from the texture and degree of structure. This relies on a look-up table and gives a range; for example, a list of typical permeability values for a variety of soils is given in Table 1.

3.2 Field measurements on intact soils

a. **Single infiltration ring:** A metal ring at least 300 mm across is driven about 50 mm into the soil surface, and water is poured into it. The time it takes for the water to soak in is timed. This method is adequate for measuring the surface infiltration rate of sandy and reasonably uniform soils.

b. **Double infiltration ring:** Two metal rings, a smaller one inside a larger one, are driven into the soil surface, and water is poured into both. The water in the outer ring blocks lateral (sideways) flow from the inner ring, so the water in the inner ring contributes solely to downward flow, which is what we measure. The method is suitable for soils that tend to swell when wet. It is no better on very sandy soils than the single ring method.

c. **Well permeameter**. A tubelike instrument is inserted into a hole drilled with an auger, and the rate at which water flows into the underlying soil is measured. This tool is good for measuring subsurface drainage in field soil at depths of 100 to 1000 mm.

3.3 Laboratory measurements on intact soils

A soil core is collected in a stainless-steel tube driven into either the surface soil or a subsurface layer carefully exposed with a sharp spade of using borehole drilling. Small cores are used for very uniform, sandy, unstructured soils. Larger cores are used for structured field soils. The collected samples shall be carefully packed so as not to disturb the soil and so artificially increase the hydraulic conductivity and should be sent to the lab for measurement.

3.4 Remoulded soil samples

Loose or disturbed samples are remoulded in the lab for measurement. This method is only suitable for unstructured sand, loamy sand, sandy loam, loam, clayey sand and fine sandy clay loam.

Table 1: Typical permeability values

k (m/s)	Natural or Engineered Materials that Typically Display this Permeability
1 to 10^{-1}	Clean gravel (e.g. SA Water sewer embedment screenings)
10^{-2}	Clean very coarse sand (single size)
10^{-3}	Clean coarse sand and gravel mix
10^{-4}	Clean medium and coarse sand mix (e.g. River Murray Monoman Formation alluvium has a permeability of 10 to 20 m/d) A good (easily compacted) TS4 pipe embedment sand
10^{-5}	Clean fine, medium and coarse sand mix (e.g. typical alluvium for smaller rivers = 0.5 to 5 m/d) An acceptable TS4 pipe embedment sand
10^{-6}	Fine and medium sand mix, silty sands
10^{-7}	Very fine sand / sandy silts / aggregated-flocculated-friable natural clays (e.g. Northern Adelaide plains clays down to about 5 m depth around Bolivar)
10^{-8}	Organic and inorganic silts / sand-silt-clay mixtures / glacial till Poorly engineered clay fill (e.g. the shoulder fill of old embankment dams in SA)
10^{-9}	Homogeneous natural clays below the zone of weathering Well-engineered clay fill (e.g. some layers in the shoulder fill of old embankment dams in SA)
10^{-10}	Homogeneous natural CH clays below the zone of weathering / Very well engineered CH clay fill with no defects (e.g. heavily remoulded say 5% wet of OMC rolled in thin layers)
10^{-11}	Over-consolidated homogeneous CH clays (e.g. sound Blanchetown or Hindmarsh Clay) Very well engineered in-situ puddle (say 10% wet of OMC) CH clay fill (Millbrook Dam core)
10^{-12}	Heavily over-consolidated homogeneous CH clays (e.g. as above, but rare) Extremely well engineered CH puddle (e.g. pug mill then in-situ puddle as per Happy Valley Dam core)

4 Use of pressure transducers to measure flow rate

4.1 Background

This Section presents a review on application of pressure transducers to measure flow rate. This section was originally prepared in November 2003 based on in house experiences in SA Water projects.

The idea of using a pressure transducer and data logger has been developed in SA Water projects to measure the *head* over some flow constriction device which could be pushed down a drainage bore. A calibration relationship between *head above and flow through* the device could then give us the flow down the bore. This approach has become more practical recently, since pressure transducers and data loggers have become relatively cheap and reliable. They can now be left in the field for months, recording readings of pressure (head) every few seconds if necessary.

The data loggers can be programmed to store each reading, or to average all readings over say one hour and store only the average, thus saving on memory space. The stored data can be downloaded direct to a PC. With a calibration curve also stored in the PC, a plot of flow versus time can be readily printed.

4.2 Laboratory development and calibration

After Hydraulics calculation and performing theoretical design of a flow constriction device, experiments in the lab was conducted at the time to get the practical details sorted out and a calibration curve produced. An experimental device in a 150 mm casing was constructed to produce a calibration curve.

5 Application in Pike-Sunlands Drainage Study

The proposed system in Section 4 was used in Pike-Sunlands Drainage Study to further evaluate its credibility. The results of the field pump testing at Sunlands carried out by Leigh Warman of the EWS Soils and Concrete Laboratory on 19/20 January 1994 showed satisfactory pump suction at all piezometers.

5.1 Relationship between flow rate and aquifer permeability

A simple calibration was established many years ago between the flow rate from a pumped piezometer and the permeability of the aquifer around the screen.

The calibration was established for a typical 50 mm diameter piezometer with a 1 m long screened section of 1 mm transverse saw-cuts at 10 mm spacing, when pumped by a small (50 to 75 mm) centrifugal pump capable of maintaining a suction of between minus 80 kPa and minus 95 kPa. The correlation was established by comparing piezometer pumping with the results of fully monitored pump tests in the Monoman Sands aquifer beneath the flats of the River Murray at Rufus River and The Yarra.

The calibration was that a flow rate of 2 L/s from a typical piezometer indicated a local aquifer permeability of 20 m/d, 1 L/s = 10 m/d, and 0.5 L/s = 5 m/d, etc.

Clearly this simple linear relationship must become invalid as the depth to groundwater approaches the suction limit of the pump (flow will ultimately cease even if the aquifer is very permeable). The relationship will also become invalid in very permeable aquifers, where the flow rate might approach the discharge limit of the pump.

Neither of these limits are generally approached when testing the Monoman Sands aquifer on the river flats, as groundwater is generally between 2 m and 6 m below the surface, and the sand is rarely more permeable than 20 m/d, which gives a flow of 2 L/s - nicely within the 3 L/s of which most small pumps are capable.

For the Sunlands pumping however, it was more likely to strike a wider range of both depth to groundwater and aquifer permeability. Therefore, it was found prudent to calibrate a pump to determine its *suction lift vs discharge* characteristics.

5.2 Laboratory calibration of pump

The idea was to determine the *suction lift* vs *pump flow* characteristics of a typical *pump and piezometer completion* when the screen of the piezometer was immersed in water. The Soils & Concrete Laboratory staff used their imagination and hoisted a pump and operator up in a "cherry picker", high above a 220-litre drum of water in which a 0.5 m long screen was immersed. The 0.5 m long screen was considered to be equivalent to a 1 m long screen half blocked by sand grains.

The results of the calibration showed a linear curve between about 3 m and 7 m of suction lift which confirms that the simple linear relationship adopted for all previous *floodplain* work was satisfactory for that purpose. The curve also indicated that where the depth to groundwater is less than 3 m or deeper than 7 m then some correction might be prudent.

5.3 Interpretation of Sunlands piezometer pumping results

The results of the pump testing at Sunlands, and an estimate of the local permeability at each piezometer are presented in Table 2.

Permeabilities in the range of 0.5 to 5 m/d (2 m/d average) are typical of the Loxton Sand Formation (fine, medium or coarse quartz sand with about 10% clay), and permeabilities of 5 to 20 m/d are typical of the Monoman Formation aquifer beneath the floodplain of the River Murray (generally medium and coarse sand with some fine sand and a trace of clay). A clean coarse sand might have a permeability of several hundred m/d, and a clean gravel several thousand m/d.

The permeabilities indicated by the piezometer pumping are therefore only typical of the Loxton Sand Formation found elsewhere in the Riverlands, and do not promise, *from this data*, to offer us an aquifer which would act as an unusually efficient drainage water collector for a comprehensive drainage system. On-farm tile drainage systems might therefore need to be as densely spaced as in any other irrigation area.

Locally, however, there may be areas where the water table is in very permeable materials, e.g. where the Norwest Bend Formation is particularly open and shelly, and/or the calcrete layer is rubbly or broken. An example of such an area is the point from which drainage water is pumped to the storage tank for reuse. It seems however that such high permeabilities should not be assumed to be the norm.

Table 2: Interpretation of piezometer pumping tests

Piezometer Number	Depth to Groundwater (m)	Flow Rate (L/s)	Estimated Local Permeability (m/d *)	Salinity EC Units
IC1 (3301)	7.80	no flow	-	-
IC3 (3003)	0.65	0.23	2	6 000
IC4 (3004)	6.57	0.34	3	8 000
IC7 (3007)	6.38	0.56	6	1 600
IC8 (3008)	5.48	1.67	17	6 500
IC9 (3009)	6.25	0.17	2	8 000
IC12 (3012)	3.90	0.03	0.3	13 000
IC13 (3013)	5.53	0.31	3	15 000
SQ2 (8002)	7.00	0.02 (unreliable)	? 0.5	(not purged)
SQ8 (8008)	8.06	no flow	-	-
*: Assumes that the completion is approximately equivalent (hydraulically) to a 1 m long by 50 mm diameter screen with 1 mm wide transverse saw-cut slots at 10 mm spacings.				