SOUTH AUSTRALIAN WATER CORPORATION

TG 10h

TECHNICAL GUIDELINE

GENERAL TECHNICAL INFORMATION FOR GEOTECHNICAL DESIGN

~ Part H ~
Permeability

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No Changes Required In the January 2007 Edition

The following lists the major changes to the November 2004 edition of TG 12h:

1. Nil

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Section 1: Scope

Section 2: Drainage Bores Flow Measurements & Permeability

2.1 Background

We have never been able to easily, accurately or cheaply measure the flow down drainage bores, as much as we have always needed that information.

I recently came up with the idea of using a pressure transducer and data logger 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 only really become practical in the last few years, 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 is downloaded direct to a PC. With a calibration curve also stored in the PC, a plot of flow versus time can be printed with ease.

2.2 Laboratory Development and Calibration

Hydraulics have had a go at a theoretical design of a flow constriction device - see attached sketch. This now needs to be developed in the lab to get the practical details sorted out and a calibration curve produced.

Would you please therefore set up an experimental device in a 150 mm casing according to the sketch, and produce a calibration curve for it.

- I have supplied a foam pig to use as the plug.
- The 3x25 mm tubes can be UPVC.
- The central insertion/removal rod can also be 25 mm UPVC. You may need to experiment a little with drilled flanges top and bottom of the pig and attached to the rod to prevent the rod slipping through the pig.
- The exact diameter of the casing should not affect the calibration too much. 150 mm UPVC could be used for the first trial in the lab, but we should ultimately trial it in a standard steel casing and in the field in case there are any practical problems with diameter and casing smoothness etc.

- The "shield" is important to prevent cascading water falling straight down the tubes.

- You will need to arrange for a steady supply of water from about 0.1 L/s up to say 5 L/s (a fire hydrant?) - so you might need to set the thing up outside!

- You do not need to know what flow is going in, although it does need to be reasonably steady.

- Measure the flow out from the bottom to say 1%. This means measuring flow for at least 100 seconds. You will therefore need a fairly big receiving tank for the higher flows (5 L/s x 100 s = 500 L).

- I recommend that you set up a sight glass for observing the head in the casing. (We do not need to trial a transducer/data logger at this stage.).

Any other details are probably best worked out by discussion so do not hesitate to call. There is some urgency on this job as the overall Pike-Sunlands Study needs to be reported on to the MDBC by next June.

This “Technical Note” was prepared by Ed Collingham, 11/11/2003
(Ex Principal Engineer Geotechnical)

Section 3: Pike-Sunlands Drainage Study

3.1 Field Pumping as Sunlands

The results of the field pump testing carried out by Leigh Warman of the EWS Soils and Concrete Laboratory on 19/20 January 1994 are attached.

Satisfactory pump suction was achieved at all piezometers.

Credible flow rates and salinity samples were obtained from all piezometers except SQ2 (Murray Group completion / depth to groundwater 7.0 m), SQ8 (Murray Group / 8.1 m), and IC1 (shallow aquifer / 7.8 m). The inability to pump from these three is considered to be due to the depth to groundwater, which is close to the suction limit of the pump. (Maximum suction for even a *vacuum* pump is of course limited by atmospheric pressure to about 10 m.)

3.2 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, we were likely to strike a wider range of both depth to groundwater and aquifer permeability. I therefore thought it prudent to calibrate a pump to determine its *suction lift vs discharge* characteristics.

3.3 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 are shown on the attached plot. The linear portion of the curve between about 3 m and 7 m of suction lift confirms that the simple linear relationship adopted for all previous *floodplain* work was satisfactory for that purpose. The curve also indicates that where the depth to groundwater is less than 3 m or deeper than 7 m then some correction might be prudent.

3.4 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 the attached table.

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 might therefore need to be as densely spaced as in any other irrigation area.

Locally, however, there may be areas where the watertable is in very permeable materials (eg 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.

3.5 Interpretation of Piezometer Pumping Tests

Table 3.1 - 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.

This “Technical Note” was prepared by Ed Collingham, 11/11/2003
(Ex Principal Engineer Geotechnical)

Section 4: Notes on Sunlands Drainage Bores Flow Measurements and Permeability

4.1 General Comments (As Discussed 27/5/96)

1. The preferred concept clearly detailed in the consultancy brief is for a combined CDS and SIS. It would seem that the consultant has gone outside of his brief by proposing, and presenting to the growers, a combined groundwater pumping scheme (GPS) and SIS as the preferred option, without first consulting PISA as project managers.

2. It appears that the GPS component of the consultant's proposal has not been prepared to the same level of detail as has previously been accorded the other options, nor has it been fully costed. This makes it difficult to even rank it with the other options at this stage, let alone put it forward as the preferred option.

4.2 Technical Comments

3. The simple language style used in 17.1, 17.2, and 17.3 is welcome and appropriate.

4. However in these sections and throughout the rest of 17 the interaction (or lack of it) between the Loxton Sand aquifer and the Murray Group aquifer is confusingly presented. All references and descriptions of the mechanisms should be scrutinised. Either:

   - the two aquifers are hydraulically well separated by the Cadell Marl aquitard (except for drainage bores) - in which case they each support separate groundwater mounds, fed largely by drainage bores. We therefore have three mounds to consider: (1) the "Blanchetown Clay perched mound", (2) the "Loxton Sand perched mound", and (3) the "Murray Group regional groundwater mound".

   - or, the two aquifers are hydraulically fairly well connected (as appears to be argued) - in which case only one groundwater mound should be referred to, leaving us with (1) the "Blanchetown Clay perched mound", and (2) the "Loxton Sand / Murray Group regional groundwater mound". This would not preclude reference to pressure differentials between the Loxton Sand and the Murray Group.

5. All references to Stockyard Plain Basin should be reviewed. Stockyard Plain basin has no spare capacity for additional inputs from a scheme the size Sunlands. Either refer to "an extension of Stockyard Plain Basin" or "a new disposal basin in the area of Stockyard Plain Basin".

4.3 Section on “Advantages and Disadvantages

6. Water does not need to be saline to be "acceptable" for disposal to a basin, indeed less saline water evaporates better.

7. All proposals aim to halt the spread of waterlogging. It makes little difference to this result whether the water is taken away before it is dropped down a drainage bore or allowed to drop down and then removed from the aquifer.

8. Preventing water going down some drainage bores (as the CDS does) will also "rejuvenate" other drainage bores.

9. To argue that higher power costs can be an "advantage" reduces credibility. If used at all, such arguments would be better applied to a CDS option, as the flows from a CDS would respond almost instantly to reduced drainage from improved irrigation, compared to a GIS pumping from a huge regional mound.

10. Are we obliged to pursue any practical reuse options? If so, or if it is desirable to do so anyway, or to retain existing ones, the argument that it is an advantage for the GIS and SIS to share a pipeline loses impact.

11. All schemes (including do-nothing) would ultimately result in the flushing of the aquifers. None would be significantly quicker than another, and all would take so long as to be outside the life certainly of the schemes and probably of the irrigation area.

12. We have discussed the apparent water balance discrepancies between the GIS/SIS proposal and the others. I have not addressed this. It needs to be pursued.

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Section 5: Typical Permeability Values

Table 5.1 - Typical Permeability Values.

k m/s (1)	**k m/d** (2)	**k mm/a** (3)	**Natural or Engineered Materials that Typically Display this Permeability** (4)	**Drainage Quality** (Agricultural)
1 to 10^{-1}			Clean gravel (eg SA Water sewer embedment screenings to SA10–7)	Excellent
10^{-2}	1 000		Clean very coarse sand (single size)	Excellent
10^{-3}	100		Clean coarse sand and gravel mix	Excellent
10^{-4}	10		Clean medium and coarse sand mix (eg River Murray Monoman Formation alluvium has a permeability of 10 to 20 m/d) / A good (easily compacted) DS4(b) pipe embedment sand	Good
10^{-5}	1		Clean fine, medium and coarse sand mix (eg typical alluvium for smaller rivers = 0.5 to 5 m/d) An acceptable DS4(b) pipe embedment sand	Good
10^{-6}	0.1		Fine and medium sand mix, silty sands	Good
10^{-7}		3 000	Very fine sand / sandy silts / aggregated-flocculated-friable natural clays (eg Northern Adelaide plains clays down to about 5 m depth around Bolivar)	Poor
10^{-8}		300	Organic and inorganic silts / sand-silt-clay mixtures / glacial till Poorly engineered clay fill (eg the shoulder fill of old embankment dams in SA)	Poor
10^{-9}		30	Homogeneous natural clays below the zone of weathering Well engineered clay fill (eg some layers in the shoulder fill of old embankment dams in SA)	Very Poor
10^{-10}		3	Homogeneous natural CH clays below the zone of weathering / Very well engineered CH clay fill with no defects (eg heavily remoulded say 5% wet of OMC rolled in thin layers)	Very Poor
10^{-11}		0.3	Over-consolidated homogeneous CH clays (eg sound Blanchetown or Hindmarsh Clay) Very well engineered in-situ puddle (say 10% wet of OMC) CH clay fill (Millbrook Dam core)	“Impervious”
10^{-12}		0.03	Heavily over-consolidated homogeneous CH clays (eg as above, but rare) / Extremely well engineered CH puddle (eg pug mill then in-situ puddle as per Happy Valley Dam core)	“Impervious”