“Using a self boring pressuremeter to obtain the permeability of fine grained soils”

presented by

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How we became interested in measuring permeability

The development of the equipment

The development of the method

Improvements to the analysis

What we have done - field results

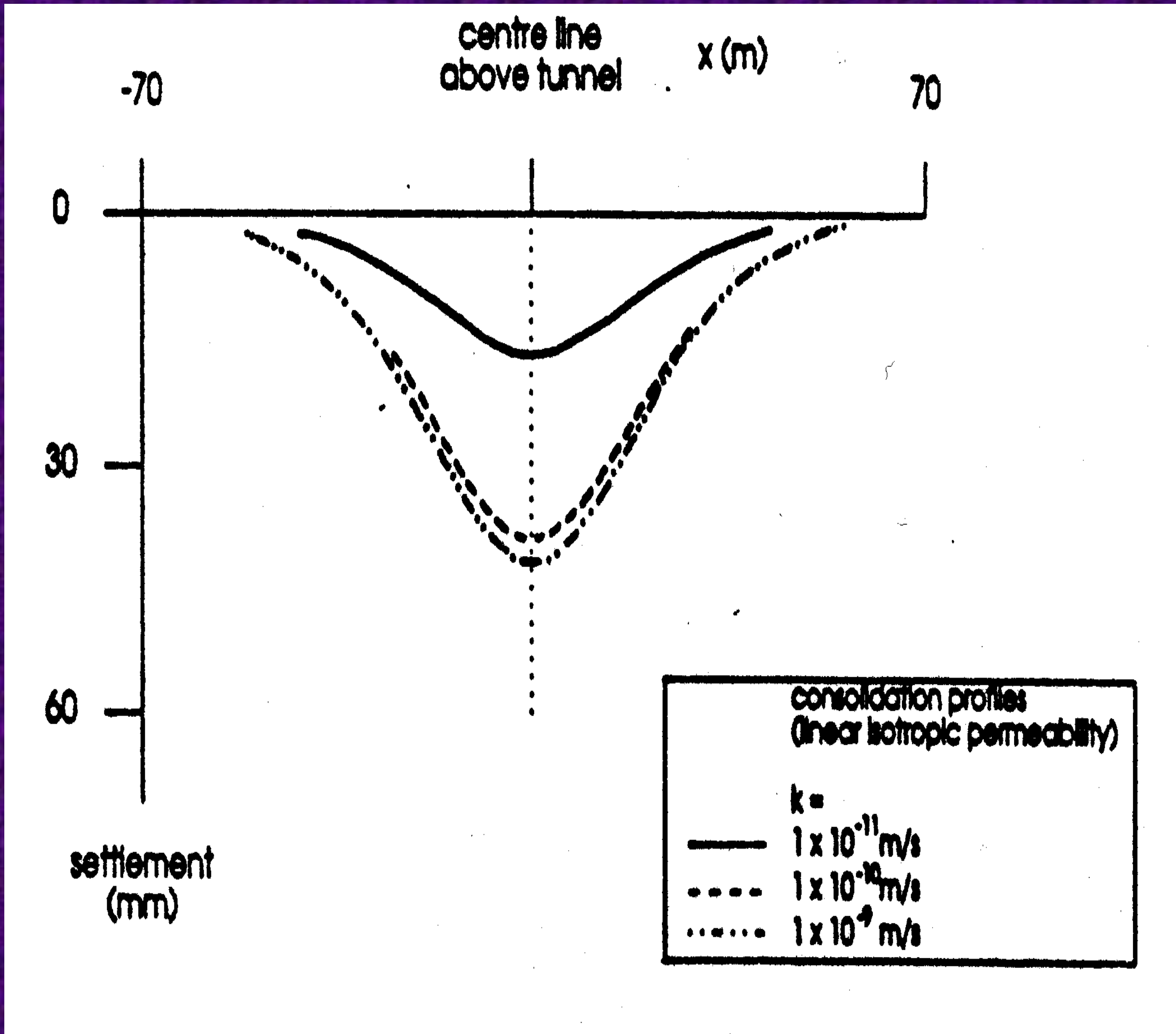
What happens next

“..Darcy’s law…contains within it one of the most variable, unreliable and unmeasurable ‘constants’ ever imagined …

Permeability covers the same range of magnitudes of velocity as are covered in the comparison between the sizes of an orange and the solar system ...”

M.Bolton 1979

Why Permeability?



Effect of permeability magnitude Addenbrooke (1996)

(F.E.M study on ground response to tunneling)

Conventional Geotechnics :

- pore pressure build up and dissipation
- engineering calculations

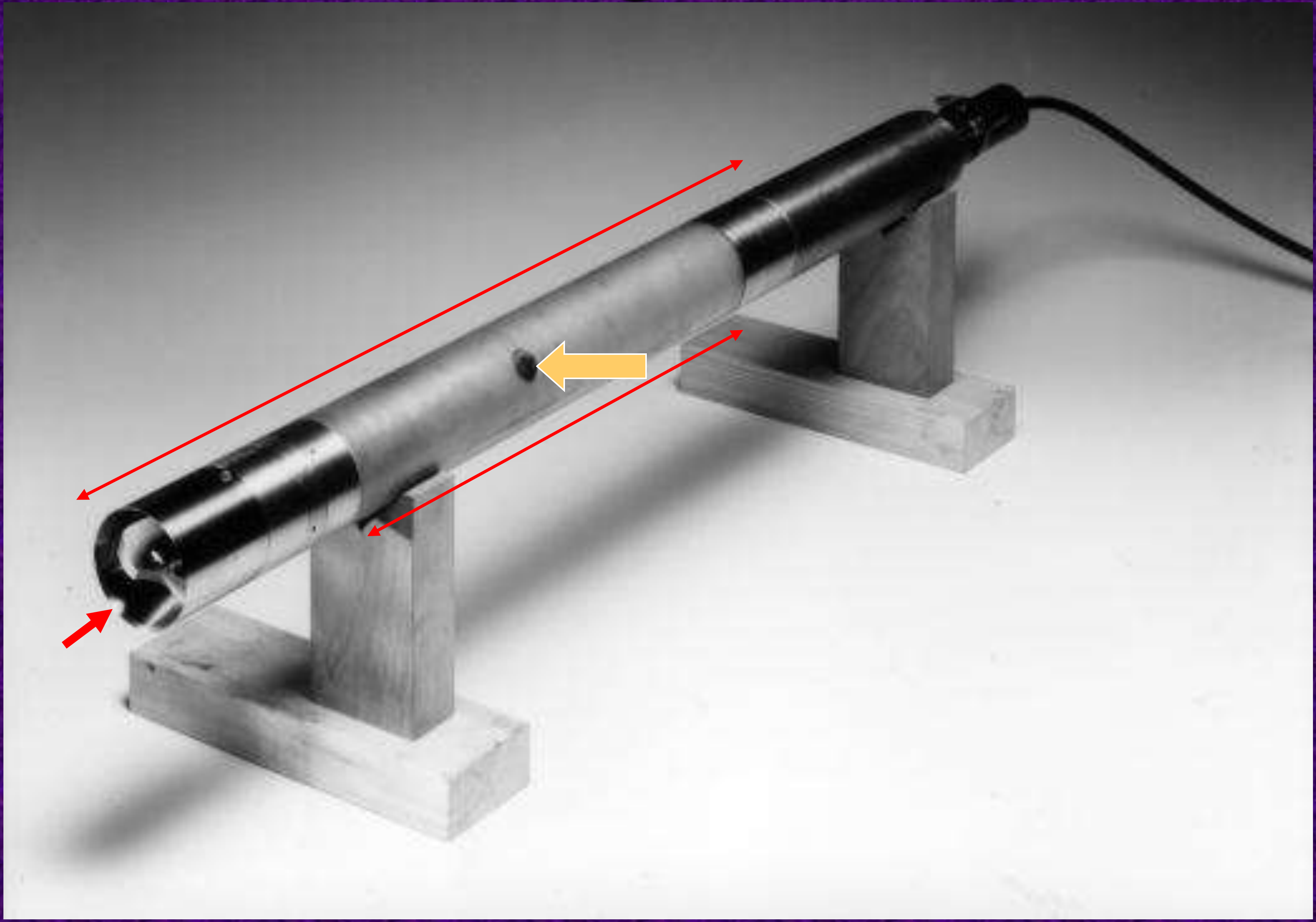
Environmental geotechnics :

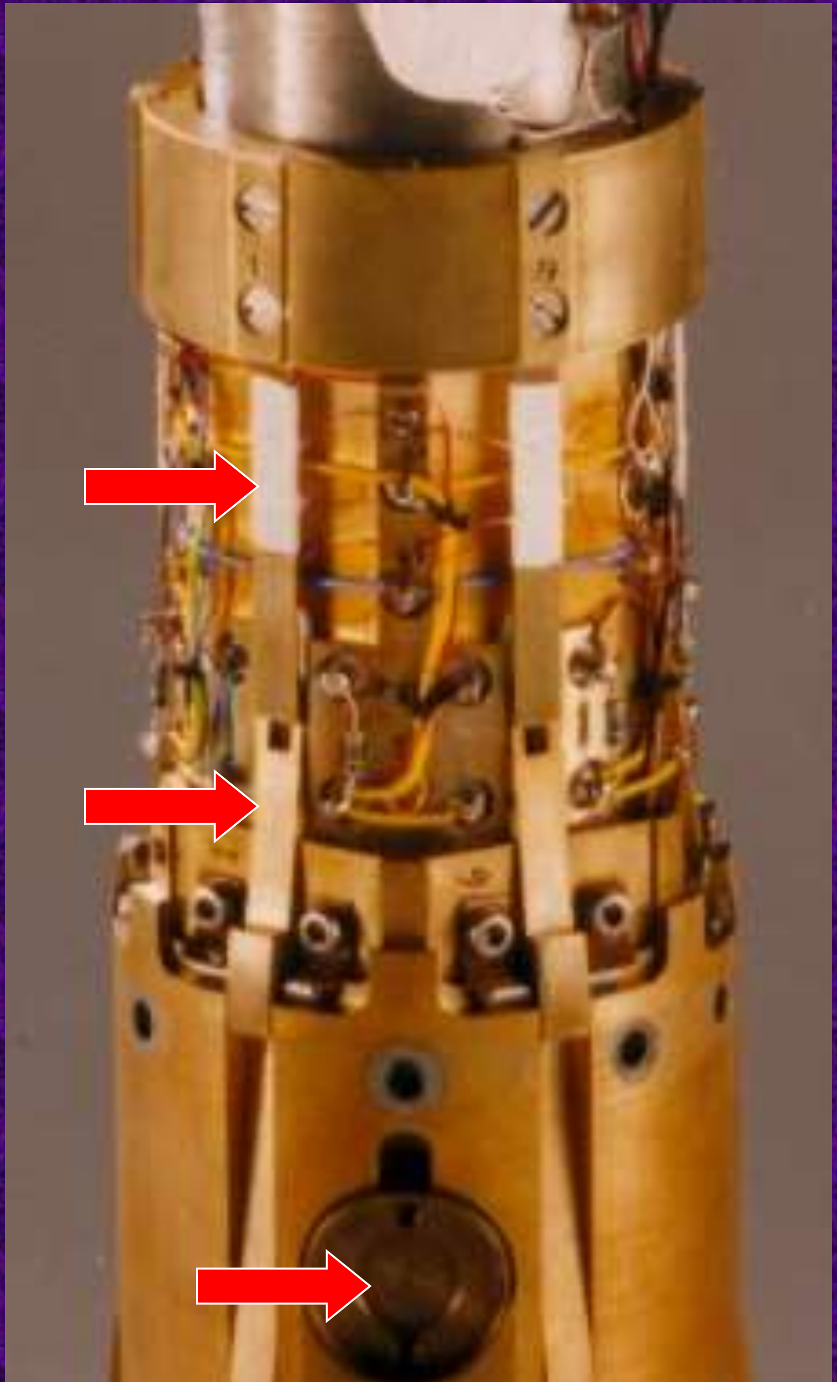
- transport of contaminants
- effectiveness of remediation and containment efforts

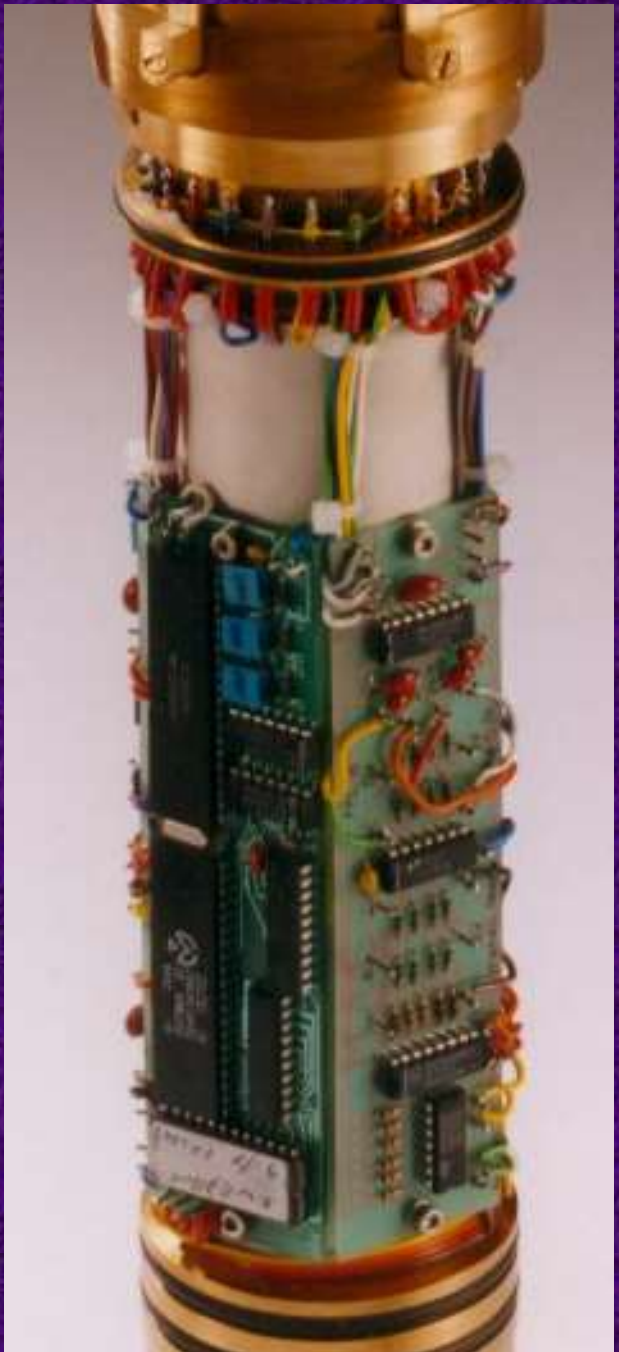
Published references :

1. **Ratnam, S., Soga, K., Mair, R.J. & Bidwell, T. (2000)**
   A novel in-situ permeability measurement technique using the Cambridge self-boring pressuremeter.
   Proc. GeoEng 2000, Melbourne, Australia
2. **Ratnam, S., Soga, K., Mair, R.J. & Whittle, R.W. (2001)**
   Permeability measurement using the self-boring pressuremeter. Proceeding of Insitu 2001, Bali, Indonesia
3. **Ratnam, S., Soga, K., Mair, R.J., Whittle, R.W. & Tedd, P. (2001)**
   An in-situ permeability measurement technique for cut-off walls using the Cambridge self-boring pressuremeter.
   Proc. of the 15th ICSMGE, Istanbul, Turkey.
4. **Ratnam, S., Soga, K. & Whittle, R.W. (2001)**
   Revisiting Hvorslev's intake factors using the finite element method. Géotechnique, Vol. 51, No.7, p.641.
5. **Ratnam, S., Soga, K., Mair, R.J. & Whittle, R.W. (2002)**
   Self-bored permeability measurements in Bothkennar clay. Géotechnique, Vol. 52, No.1, p.55
6. **Ratnam, S. & Soga, K. (June, 2001)**
   An evaluation of geometric factors used in the Two-Stage Borehole Test (ASTM D6391-99) using the Finite Element Method. A paper submitted to the ASTM Geotechnical Testing Journal (accepted March 2002).
7. **Ratnam, S (2002)**
   Development of a novel self-boring permeability measurement technique. PhD Thesis, University of Cambridge
8. **Ratnam, S. , Soga, K. , Whittle, R.W. , (2005)**
   A field permeability measurement technique using a conventional self-boring pressuremeter. Géotechnique, 55. pp. 527-537

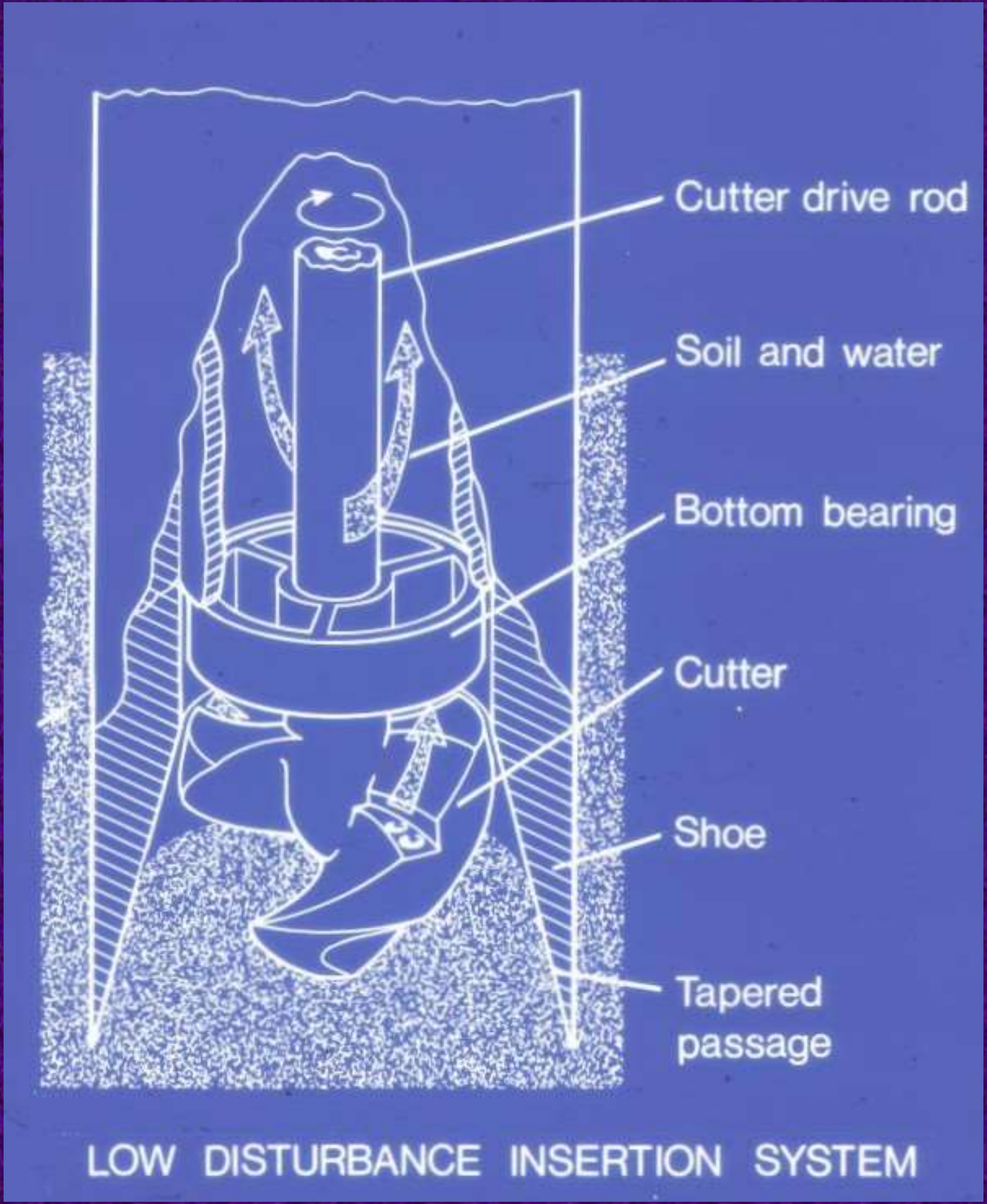
The Self Boring Pressuremeter





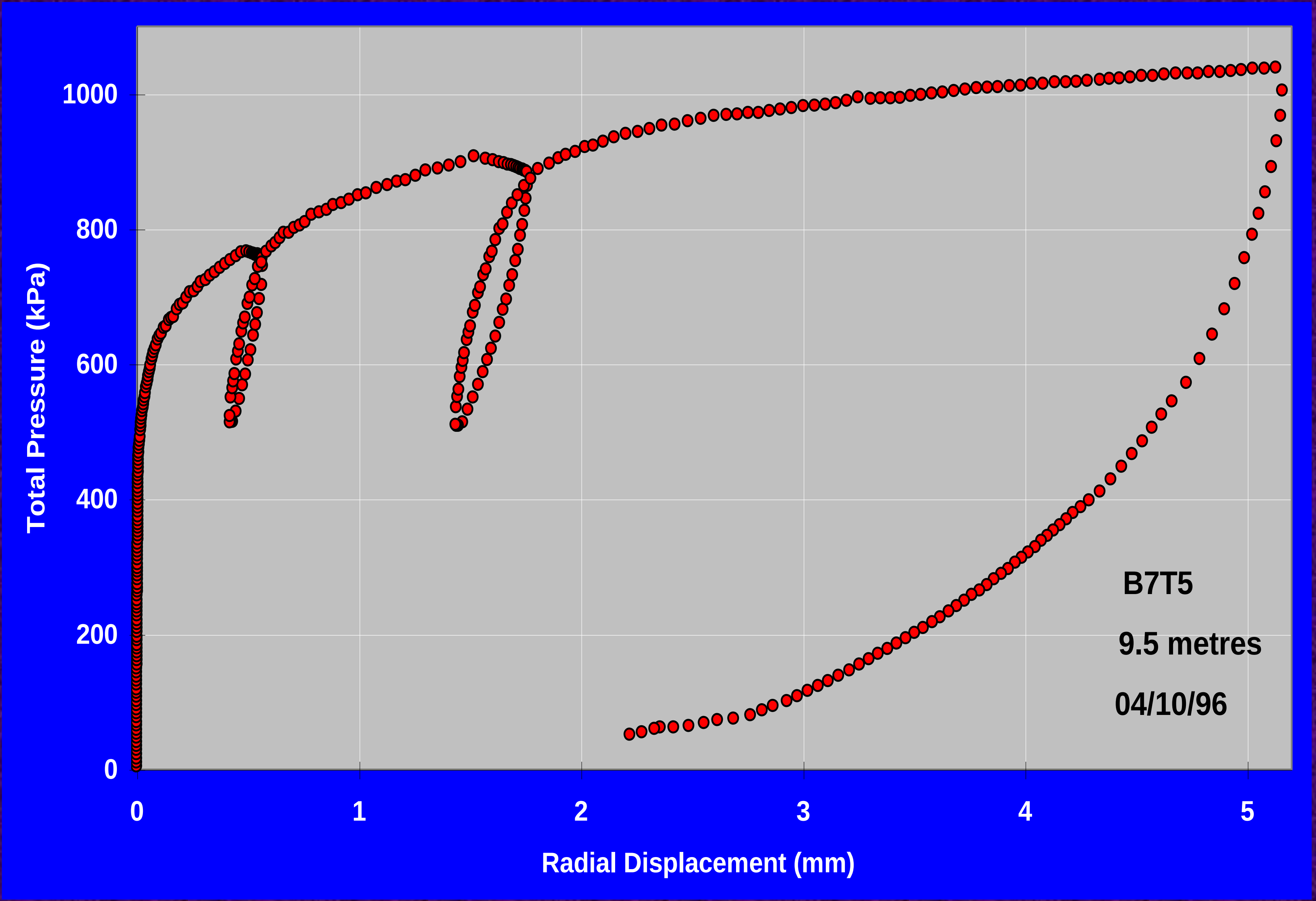


6 Arm
SBP
Mk X



Low disturbance insertion system

Typical SBP test curve in clay

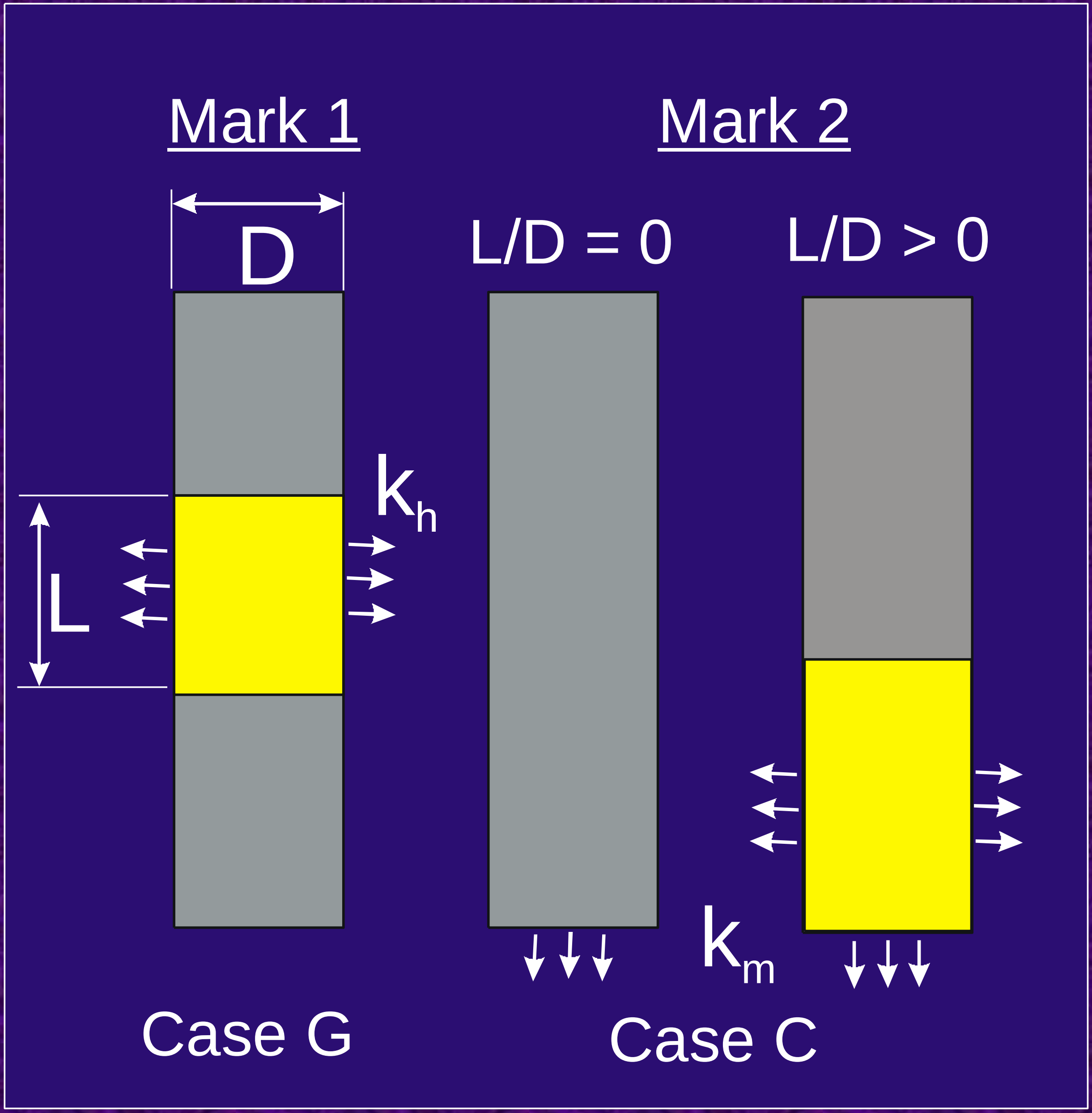


Mk 1 Self boring permeameter kit

Cambridge Model: Mark I system

- Constant flow
- Used in Kennington Park SBPM with overlay
- L=500mm, D=100mm, L/D~5
- Membrane not inflated - can be if required
- Two diametrically opposite transducers on membrane per SBPM

Deriving the shape factors - configurations under test

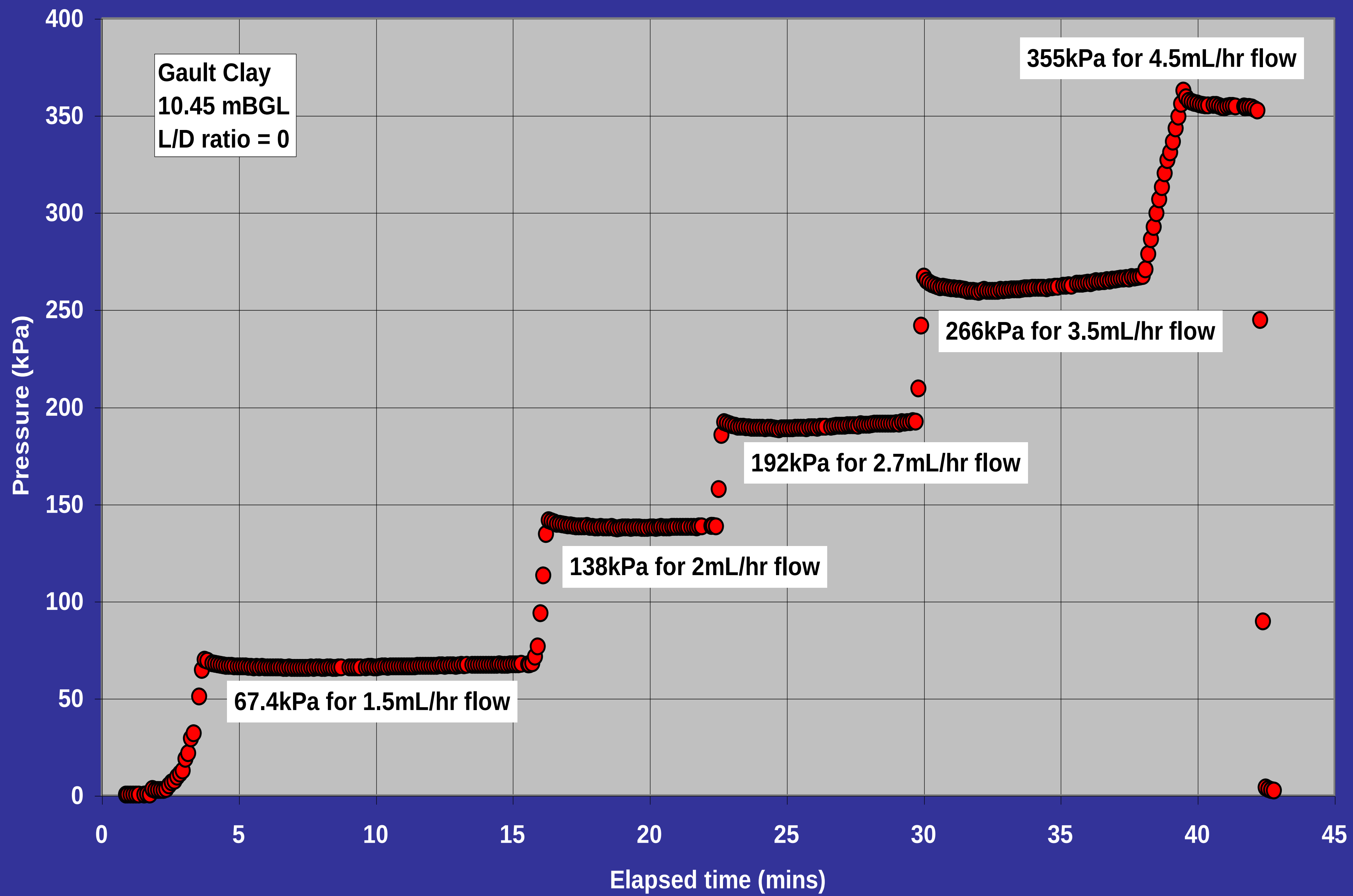


DARCY'S LAW

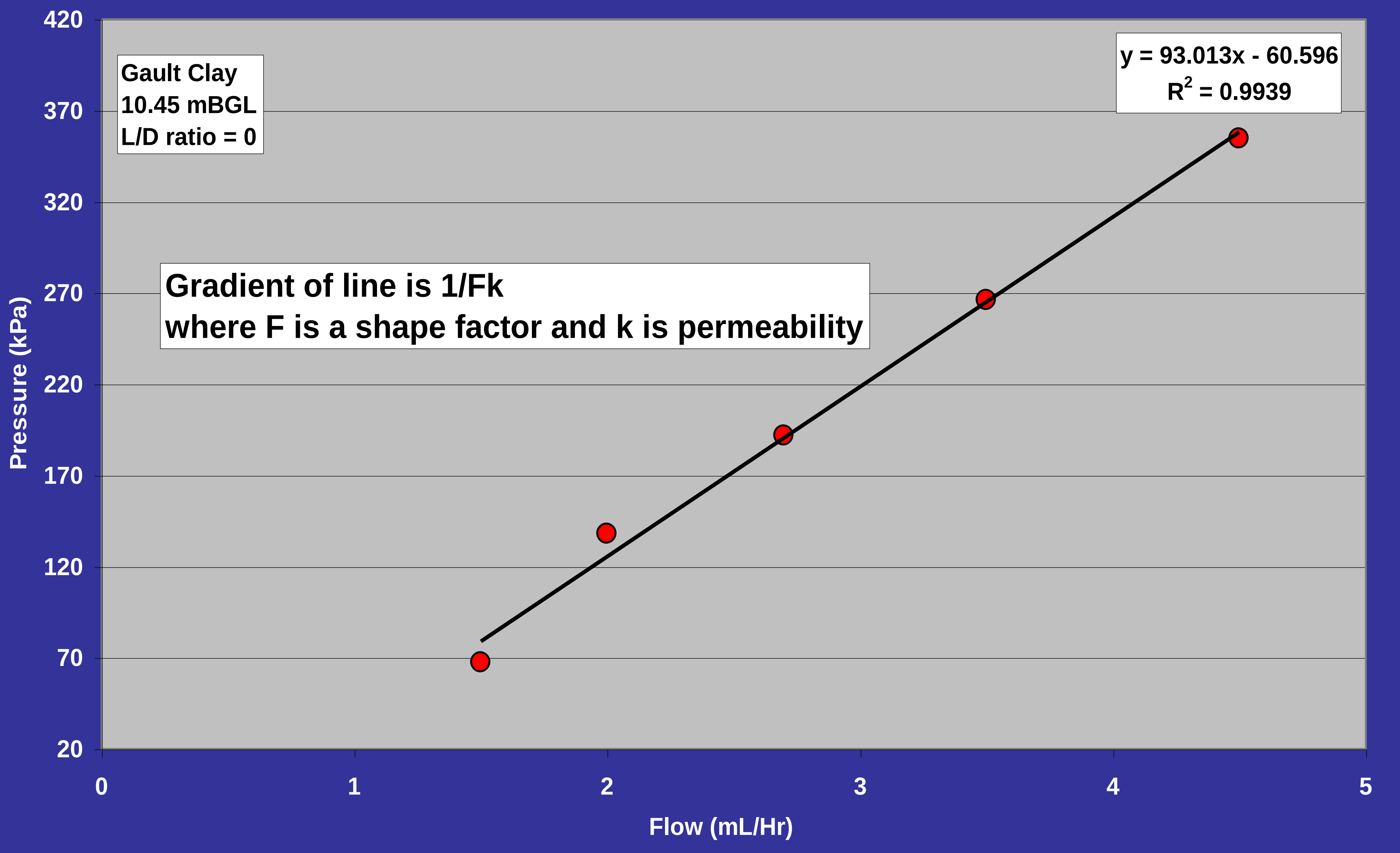
k = Q_∞/FH where

Q is rate of flow
F is a shape factor
H is head of water
&
k is a constant,
the coefficient of permeability

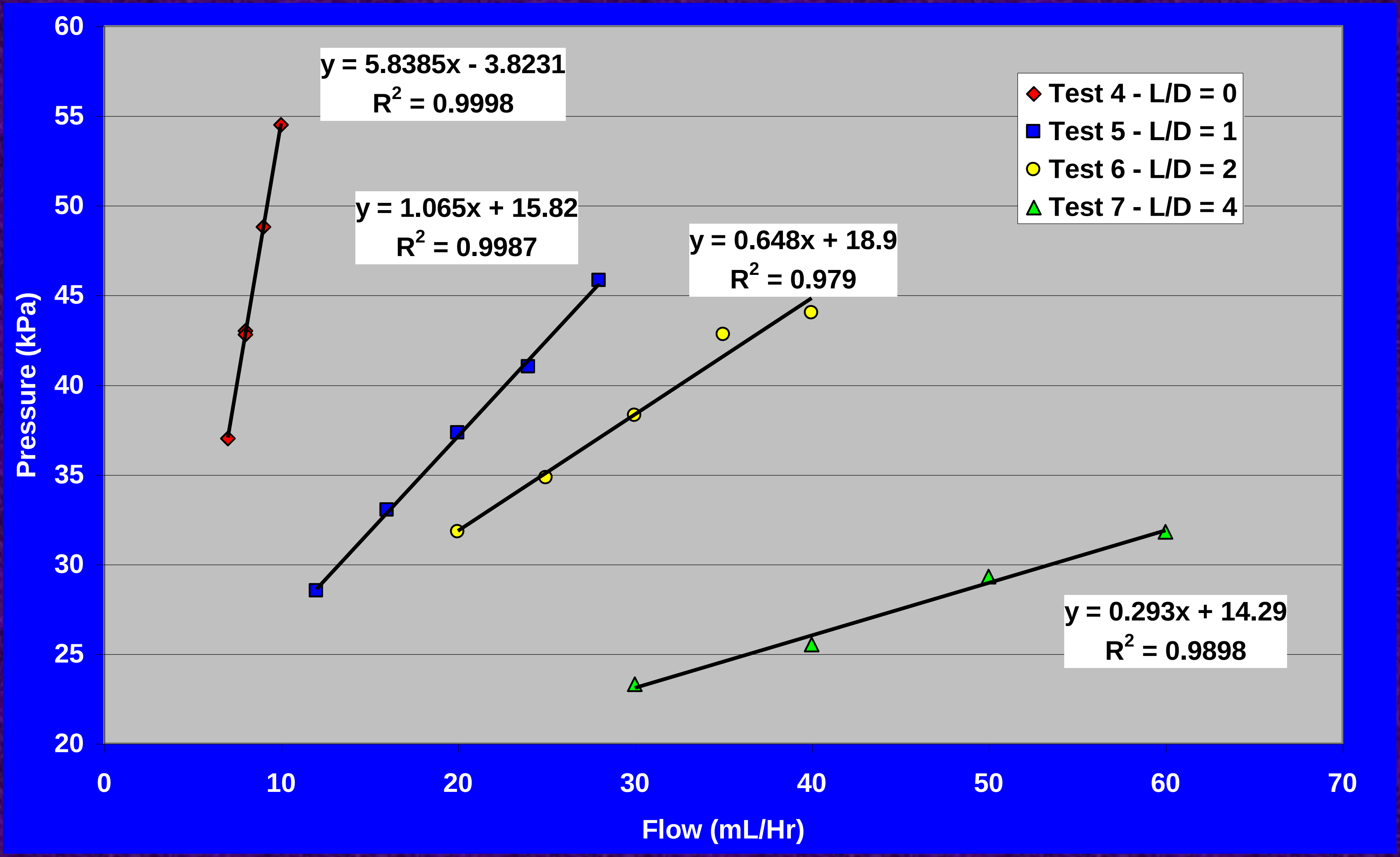
Constant flow permeameter test - Rectory Farm



Deriving permeability - an example in Gault clay



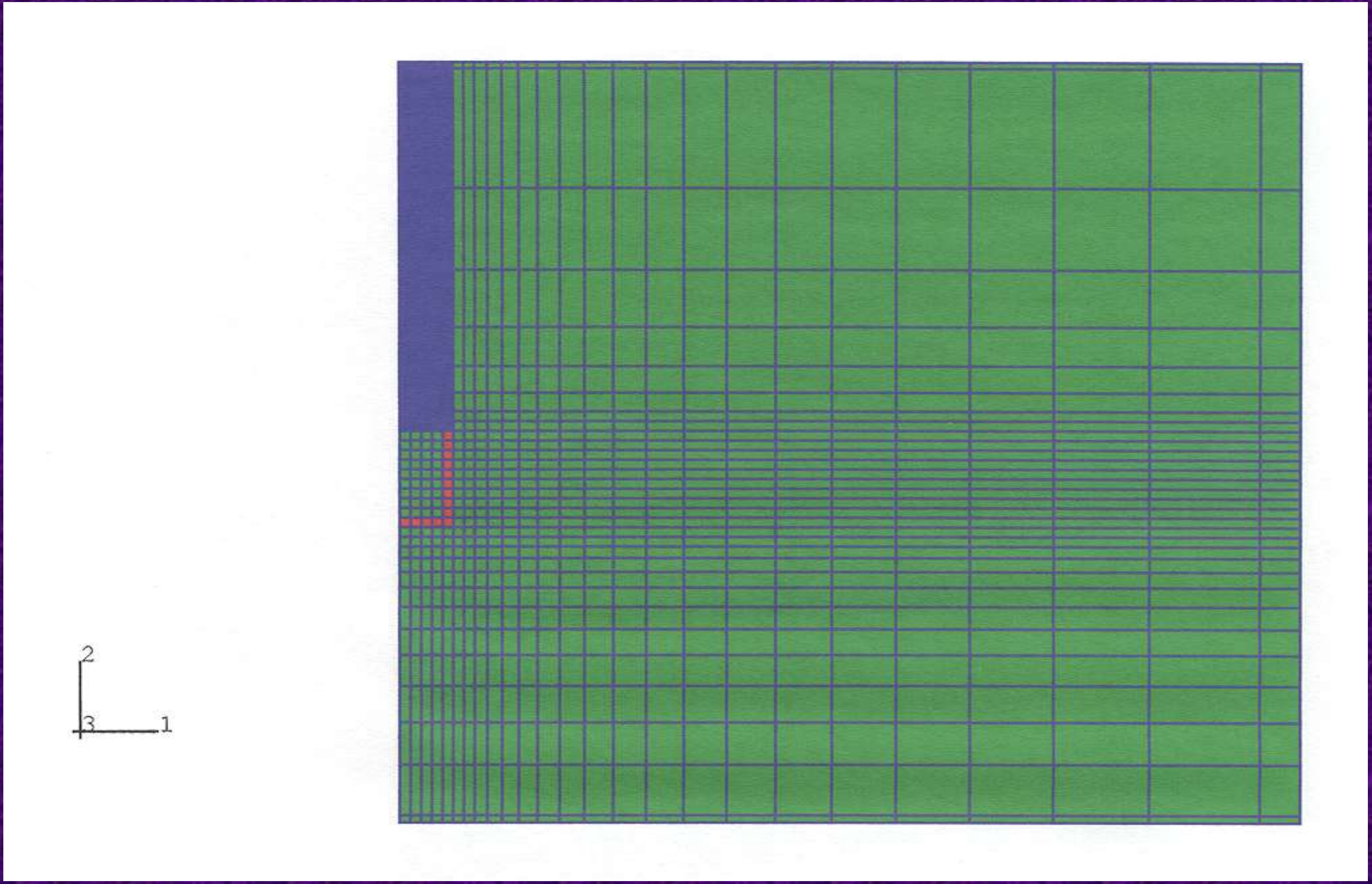
Mk 2 permeameter at Bothkennar, 6.0 metres



Issues / Difficulties

- Effect of smear zone due to installation and pull-back
- Hydraulic short circuits - i.e leaks in the casing joints
- Hydraulic fracturing
- Influence of unloading the cavity
- Inappropriate shape factors
- Temperature variation

ABAQUS Mesh - Mark II Probe



Shape factors

For Mark 1 -

$$\frac{F}{D} = 0.5691\left[m*\frac{L}{D}\right] + 5.2428\left[m*\frac{L}{D}\right]^{0.5}$$

For Mark 2 –

$$\frac{F}{D} = 1.1872\left[m*\frac{L}{D}\right] + 2.4135\left[m*\frac{L}{D}\right]^{0.5} + 3.1146$$

Where *m* is the transformation ratio for anisotropic soils $[k_h/k_v]^{1/2}$

Constant Flow Test

- Identical to constant head test
- Opposite measurement - maintain constant flow rate, measure pressure response - appropriate for low permeability materials
- Permeability from Darcy's Law

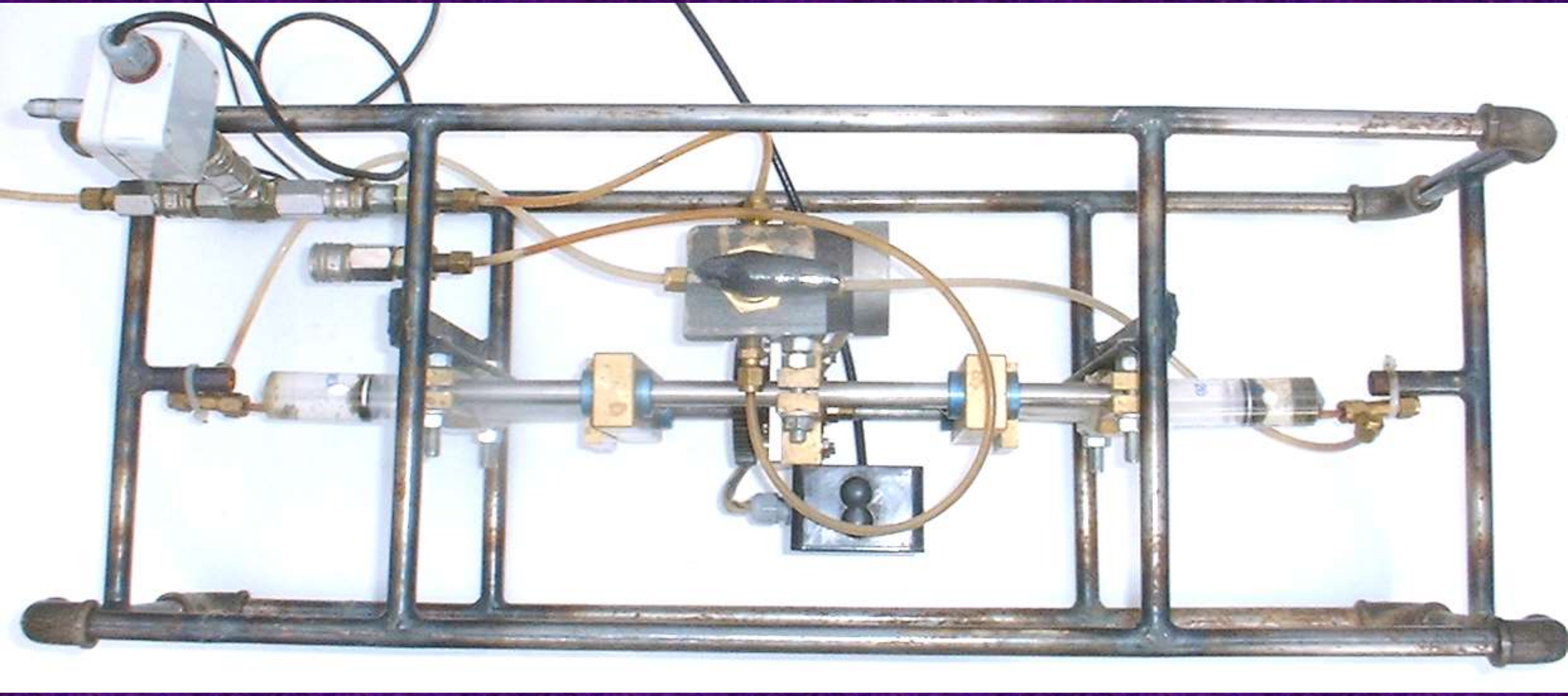
Advantages

- Head increase during a test is gradual and relatively small
- Prolonged flow readings are not required (an issue with constant head)
- Real time transducer readings - steady state is easily established

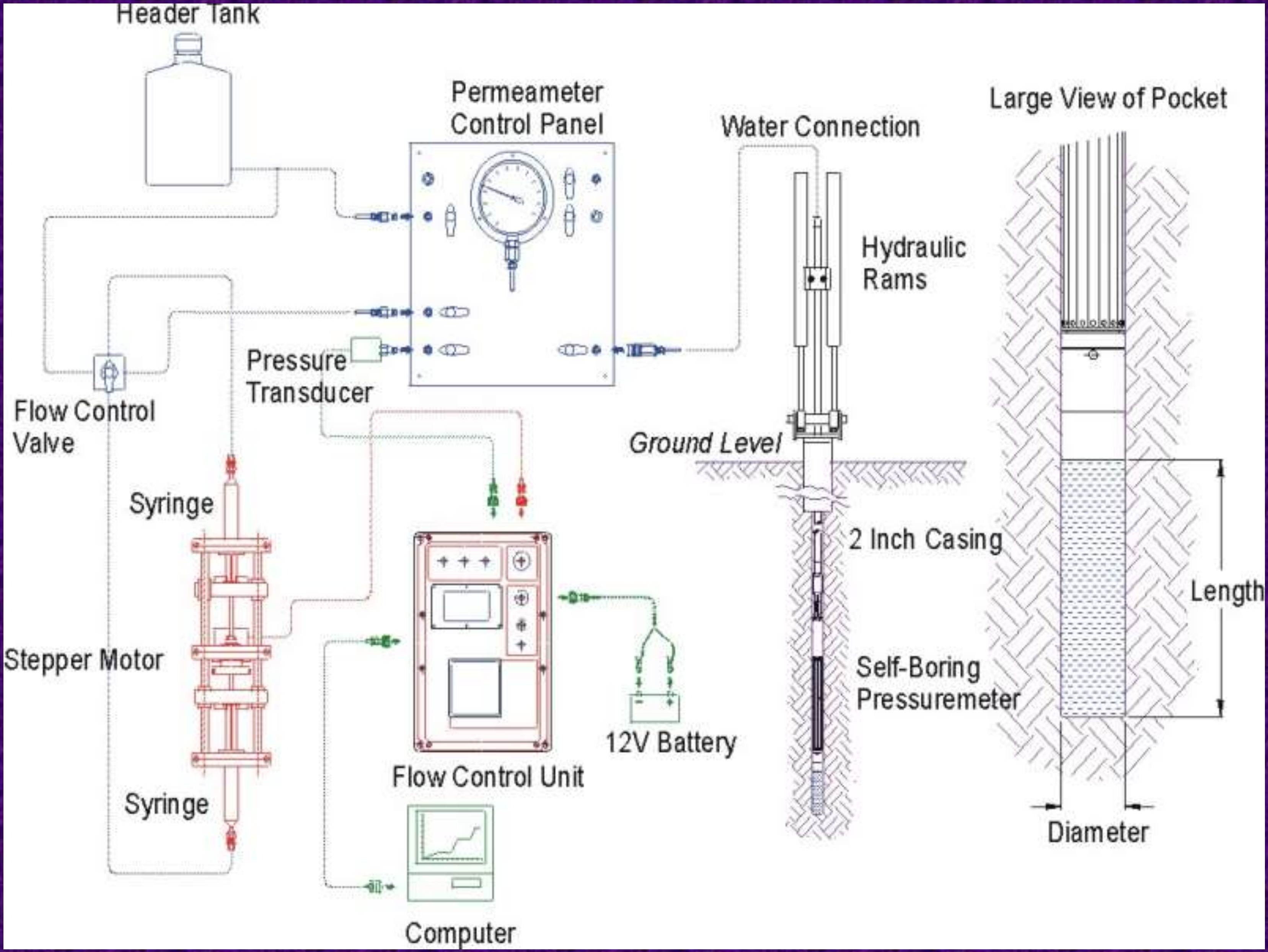
Permeameter Control Unit

1) RS232 output
2) Keypad to 'dial-in' flow rate
3) LCD read-out of flow rate
3) Drive for flow pump
4) Input for pressure cell
5) Input for temperature sensors
4) Operates from 12v battery

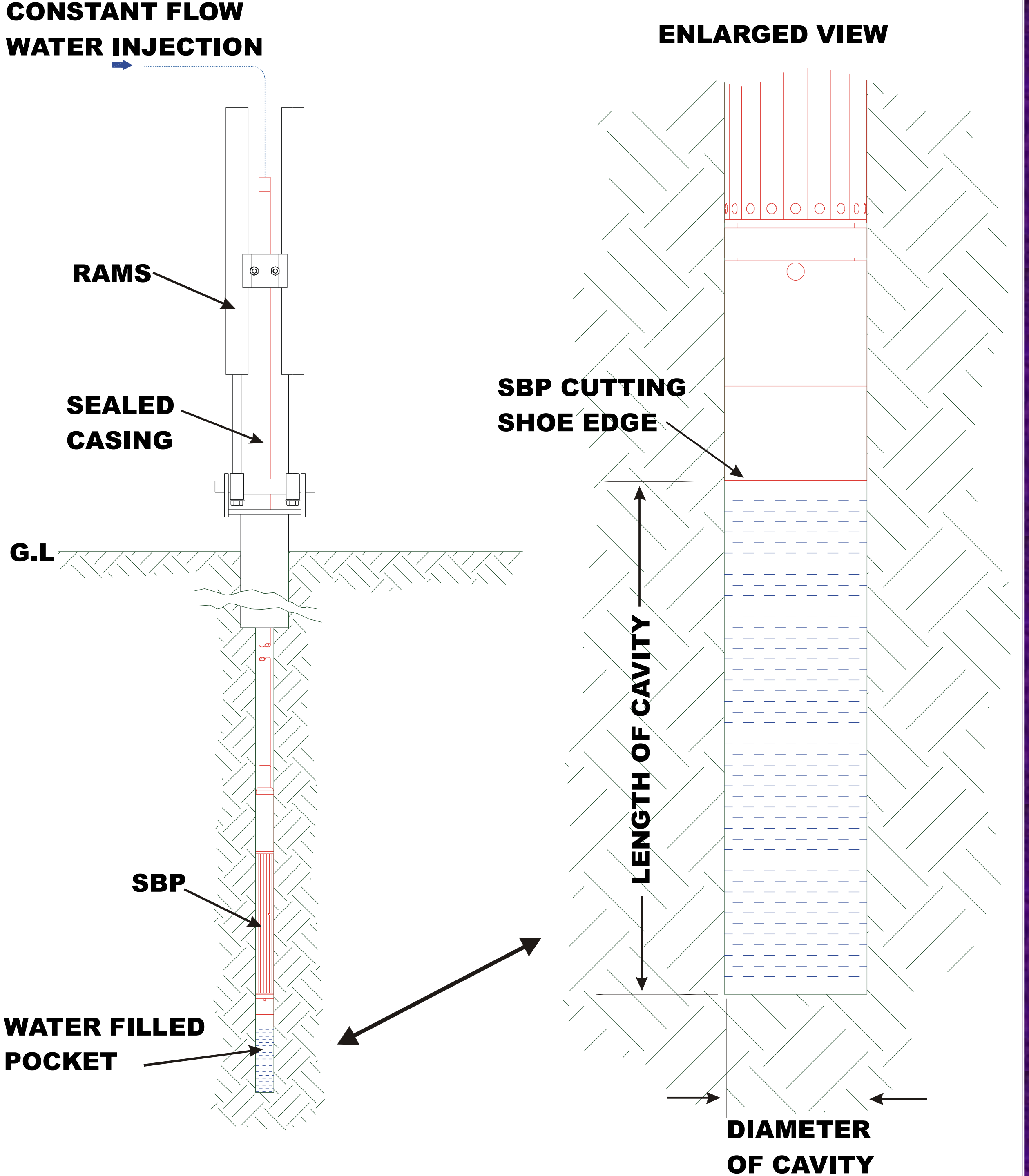
Permeameter Flow Pump



Self-boring permeameter system diagram



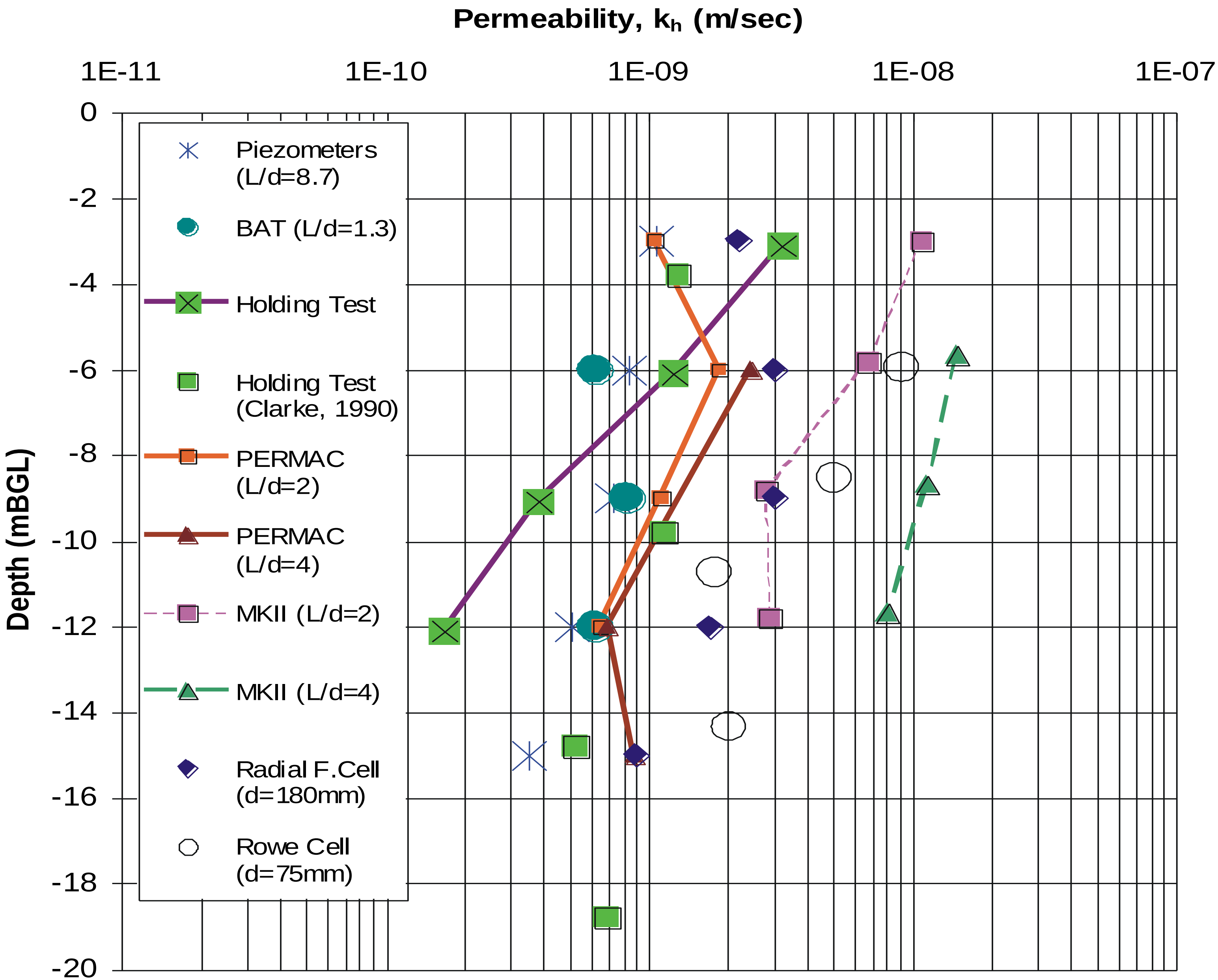
The Mk 2 Permeameter System



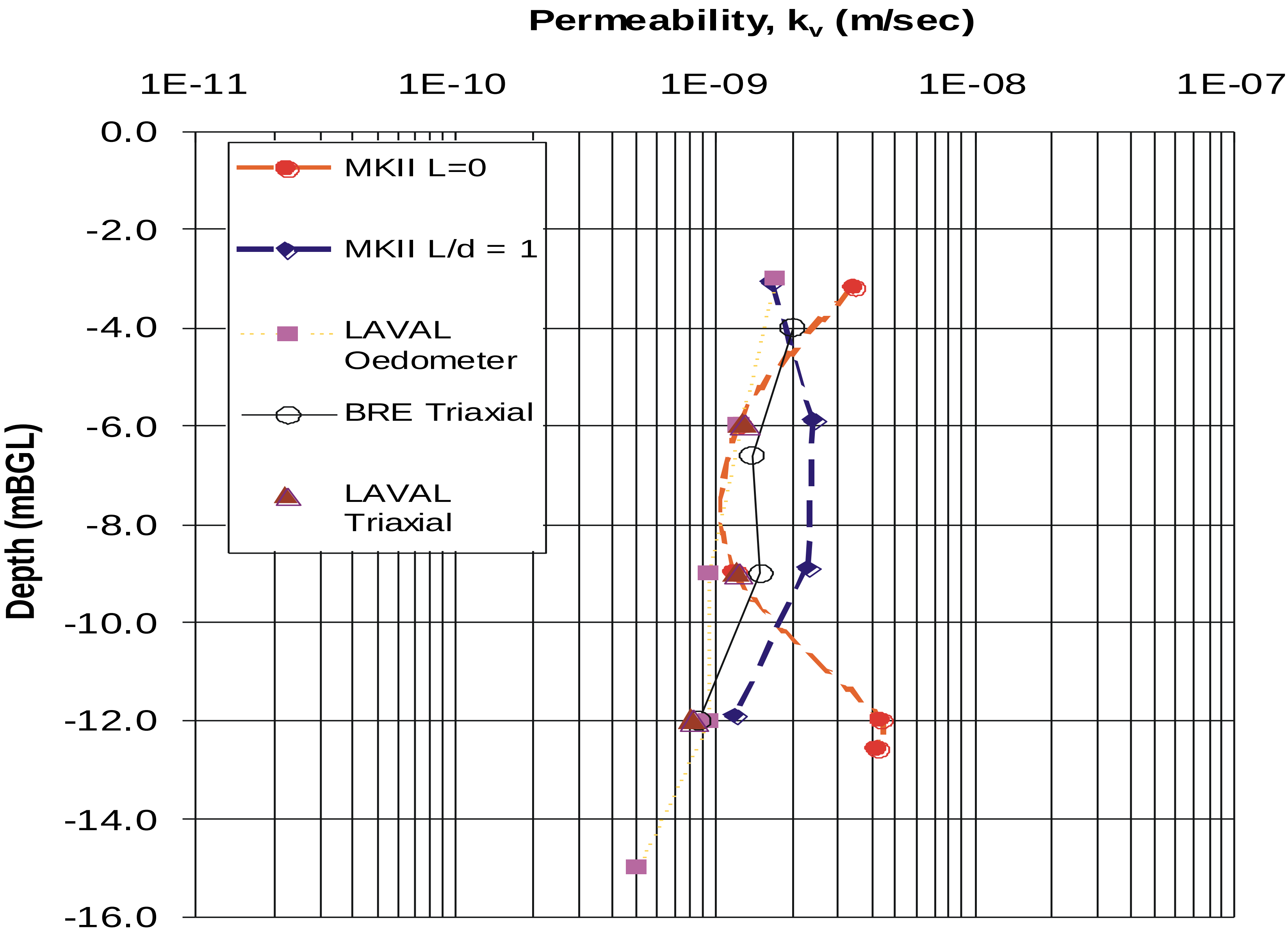
Permeameter testing - Cut-off walls

2000

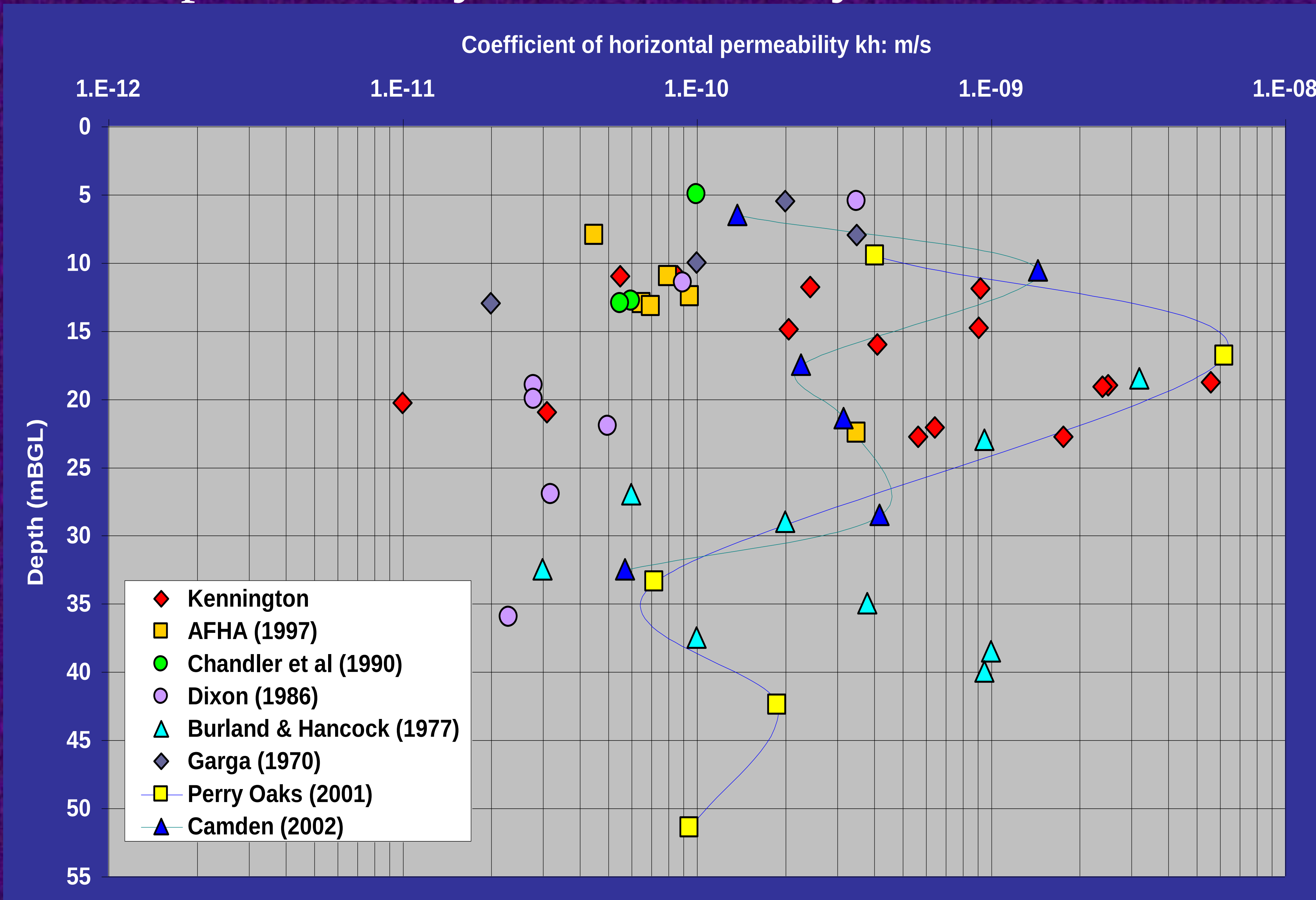
Bothkennar soft clay site - Collected results, k_h



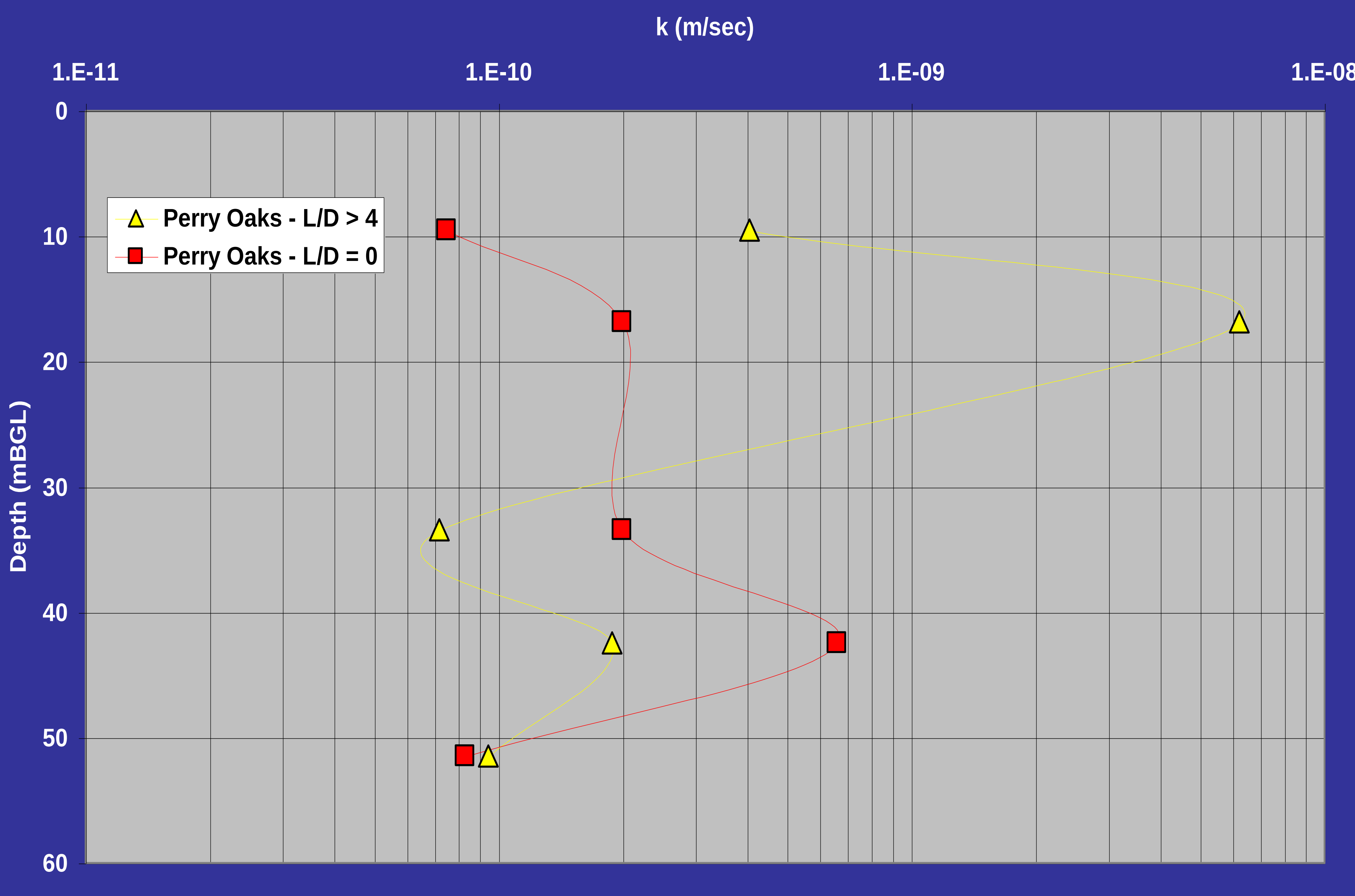
Bothkennar soft clay site - Collected results, k_v



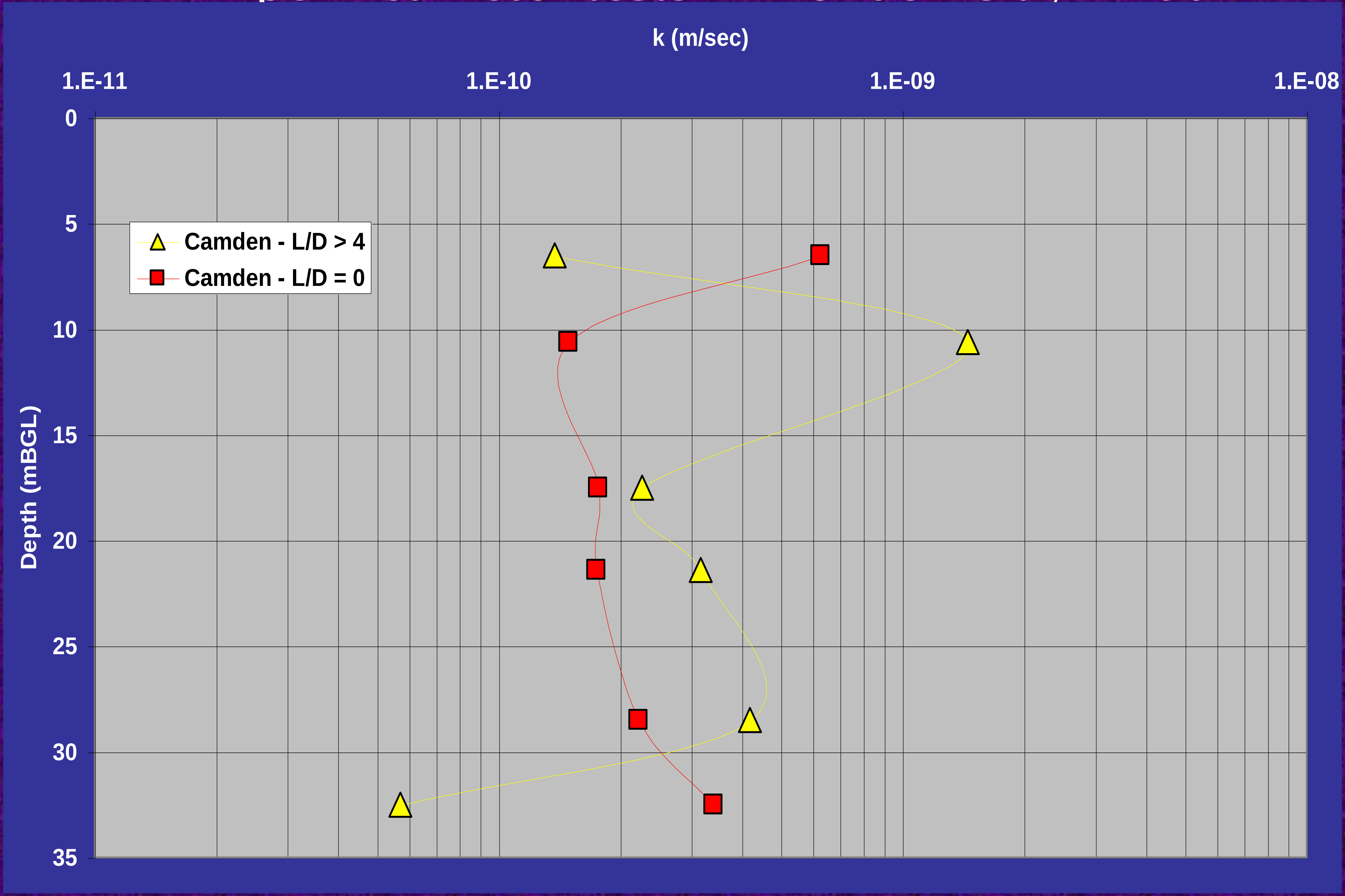
The permeability of London clay - various methods



Mk2 permeameter tests in London clay - 2001

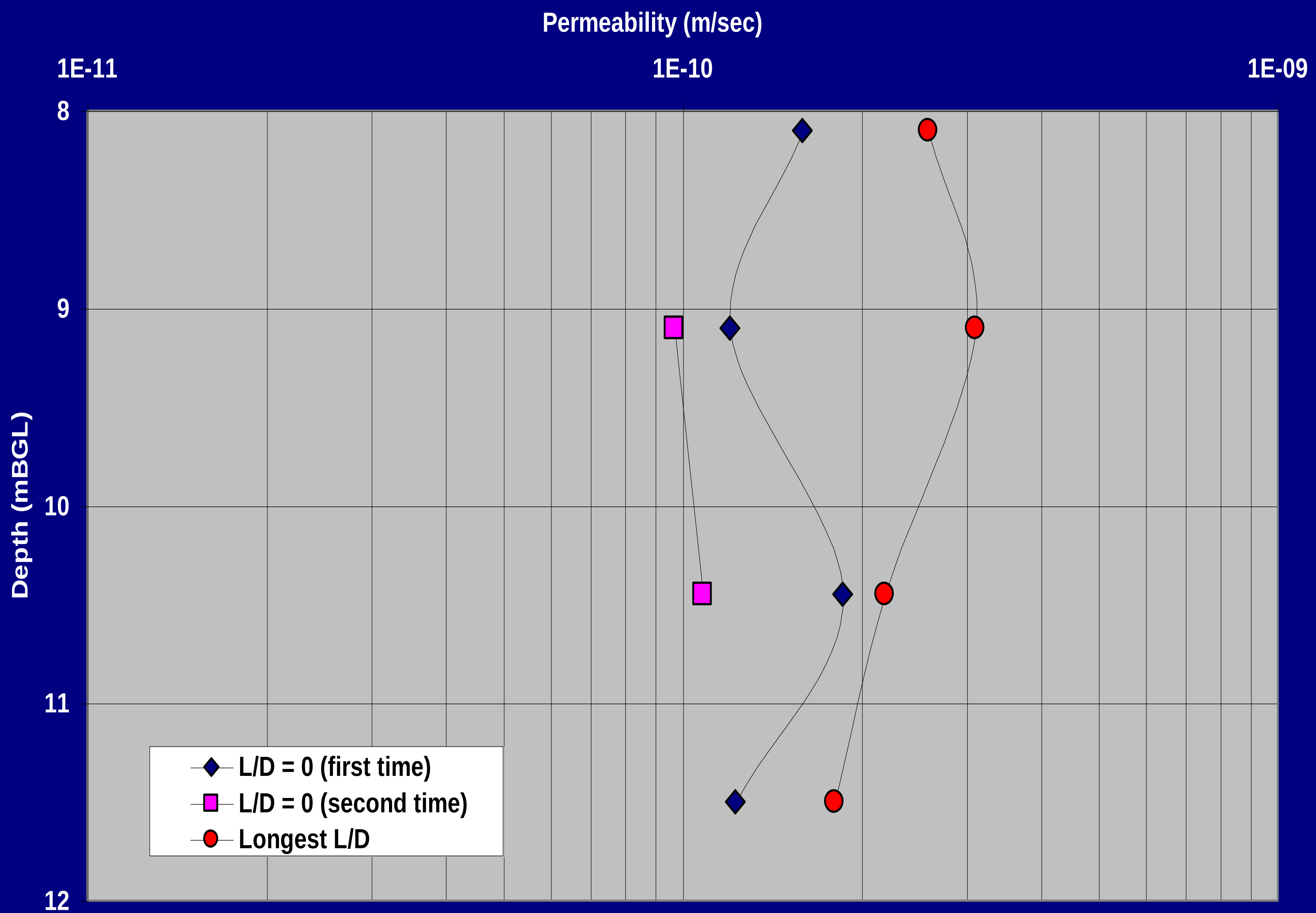


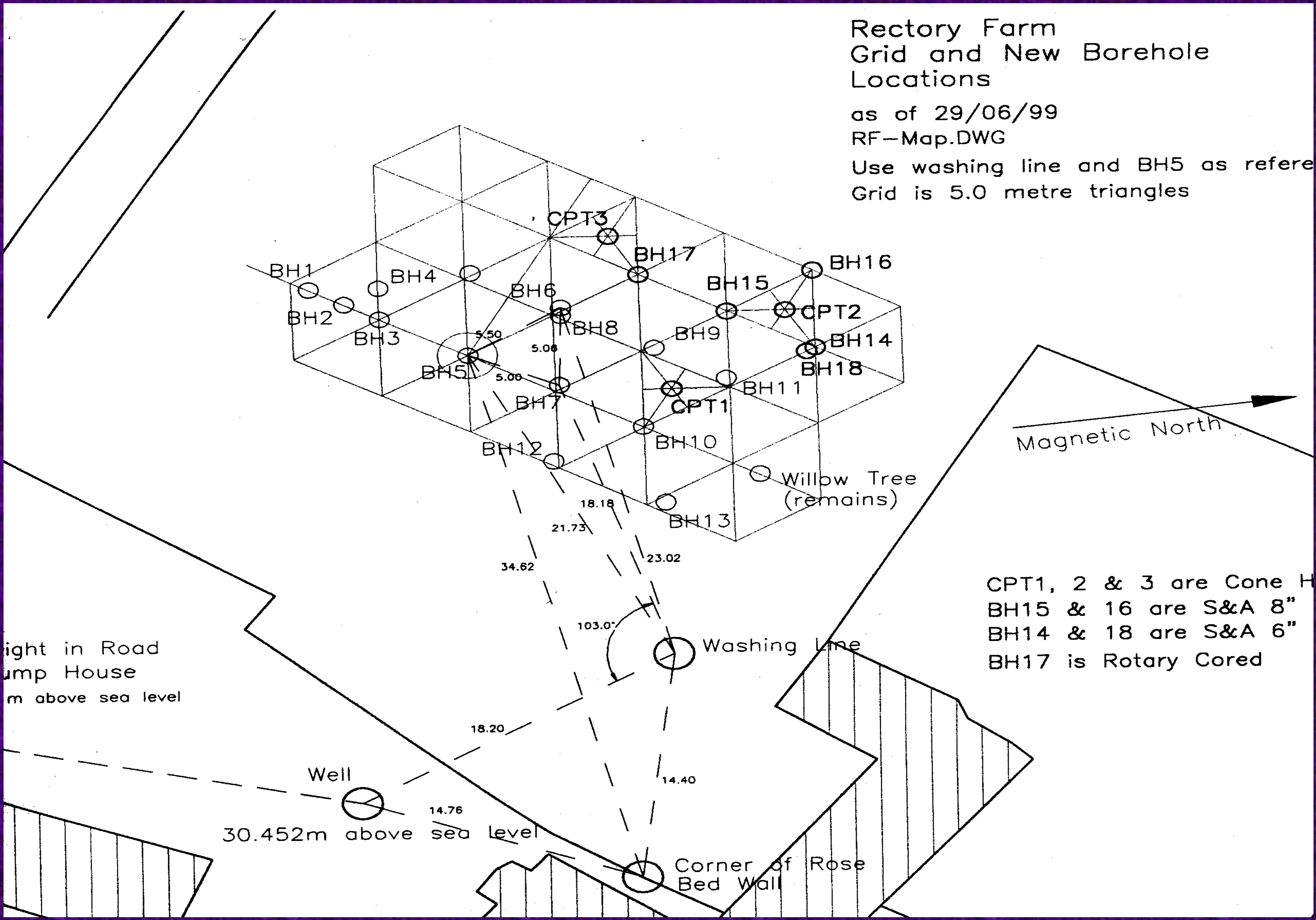
Mk2 permeameter tests in London clay - 2002



The internal full face cutter

Rectory Farm Mk2 permeability testing in Gault clay - 2002





Rectory Farm, Little Eversden, Cambridge - Plan

Cambridge Model: Mark 2

- NOT a purpose built instrument - focus is on technique not equipment
- Uses SBPM with constant flow delivery add-on at ground level
- Self bore to test depth - carry out a conventional quick undrained test
- Carry out a permeameter test in a ‘ zero length’ pocket - gives k_m
- Pull back to carry out permeameter tests in longer pockets to obtain k_h