Before we start

- Welcome to this preview of the Cromer Constant Head Permeameter.
- In Microsoft PowerPoint, the preview is best viewed as a full-screen 'Slide Show' presentation. If your current view is smaller, we strongly recommend you go to 'Slide Show' on the menu bar above, and select 'View Show' from the drop-down menu.
- To move from one slide to the next within the Slide Show, left-click your mouse (anywhere on your screen will do) or use the up and down arrow keys.
- To end the Slide Show at any stage, right-click and select 'End Show' from the drop-down menu.
- To revisit a slide from within the Slide Show, use the up arrow, or right-click and select 'Go' and 'By Title' from the drop-down menu.

If you need to, choose 'View Show' now. Left click to go to the next slide. Right click to navigate or end the slide show. This message will not be repeated.

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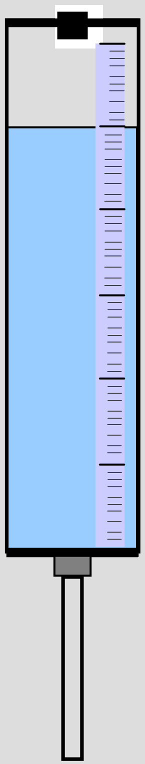


The
CROMER
CONSTANT HEAD
PERMEAMETER
- a Preview

Bill Cromer B.Sc. Hons (Geology)

June 2015

What does the permeameter do?

The Cromer Constant Head Permeameter is designed to measure the hydraulic conductivity (commonly called 'permeability') of near-surface, unsaturated soils, sediments, fractured rocks, fill, or any other suitable material, under constant head field conditions.

The test is usually done in a shallow, circular, augered hole.

The practical range of permeabilities able to be measured with the instrument is between about 0.005 and 10 metres per day (m/day).

Why was the permeameter conceived?

The permeameter was conceived primarily to aid in the assessment of soils and sites for in-ground wastewater disposal (for example, using the Trench®3.0 software package), but it has many other uses.

The range of permeabilities able to be measured (from about 0.005 m/day to about 10 m/day) spans the range of permeabilities of most soils, including those most suitable for wastewater disposal.

What does constant head mean?

‘Constant head’ means that a constant depth of water is maintained in the test hole during the permeability test. The test measures the <u>rate of flow</u> of water into the hole from a graduated reservoir.

This contrasts with the ‘Falling head’ or ‘Percolation test’ method, which measures the <u>rate of fall</u> of the water level in a test hole. Falling head tests are generally discouraged.

Test only unsaturated materials

Although the permeameter can be set up to measure permeabilities *below* a water table, the equations provided in the Manual and in this slide show are applicable only to unsaturated materials *above* a water table.

Unless you are able to apply the correct equations for saturated conditions, you should use the instrument to test only unsaturated materials.

Units of permeability

Permeability is a measure of the volume of fluid moving through a cross-sectional area in a given time.

Units can therefore be, for example, cubic metres per day per square metre, cubic centimetres per second per square centimetre, etc. These two examples reduce to metres per day (m/day), and centimetres per second (cm/sec) respectively.

Other commonly used units are cm/min, cm/sec, m/sec, and in the imperial system, ft/day.

In the Instruction Manual, permeability is expressed in m/day.

Materials and their permeabilities

Typical ranges of permeability for naturally-occurring materials are:

	m/day
Clay soils at the surface	0.01 to 0.2
Clays at deeper levels	10^{-8} to 10^{-2}
Clay, sand and silt mixtures	0.01 to 1
Sand (fine grained)	1 to 5
Sand (medium grained)	5 to 20
Sand (coarse grained)	20 to 100
Gravel	100 to 1000

Equipment supplied with the permeameter

The basic package contains the following equipment:

- one clear polycarbonate, 4.5 litre, graduated water reservoir, fitted with an (optional) valve (tap) at the bottom and a rubber bung at the top,

- four 20mm diameter delivery tubes of various lengths,

- two 50mm diameter PVC slotted screens, and assorted fittings,

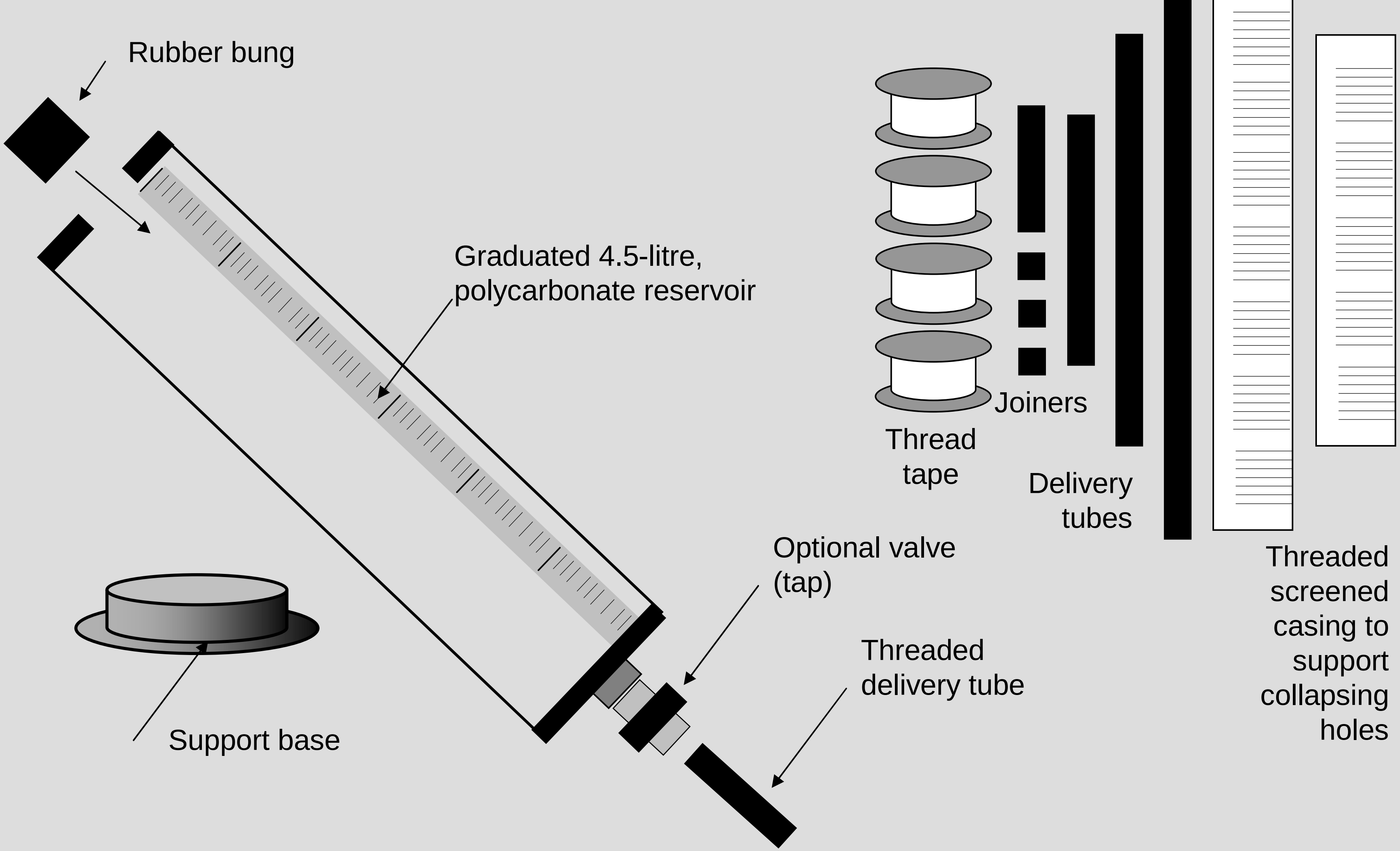
- reels of thread tape for airtight seals on the delivery tubes,

- a hard-copy Instruction Manual, various files on a storage device,

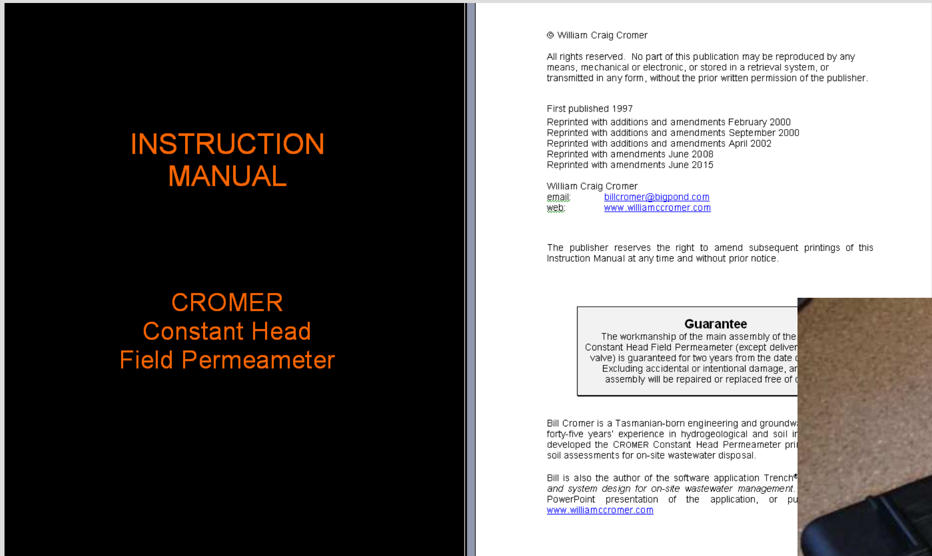
- a basal plate to support the instrument over the test hole, and

- a robust carry case.

Equipment supplied with the permeameter



Equipment supplied with the permeameter



INSTRUCTION
MANUAL

CROMER
Constant Head
Field Permeameter

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The publisher reserves the right to amend subsequent printings of this Instruction Manual at any time and without prior notice.

Guarantee
The workmanship of the main assembly of the
Constant Head Field Permeameter (except
valve) is guaranteed for two years from the date
Excluding accidental or intentional damage,
assembly will be repaired or replaced free of

Bill Cromer is a Tasmanian-born engineering and
forty-five years' experience in hydrogeological and soil
developed the CROMER Constant Head Permeameter
soil assessments for on-site wastewater disposal.

Bill is also the author of the software application Trench®
and system design for on-site wastewater management.
PowerPoint presentation of the application, or
www.williamccromer.com

Instruction manual and
carry case

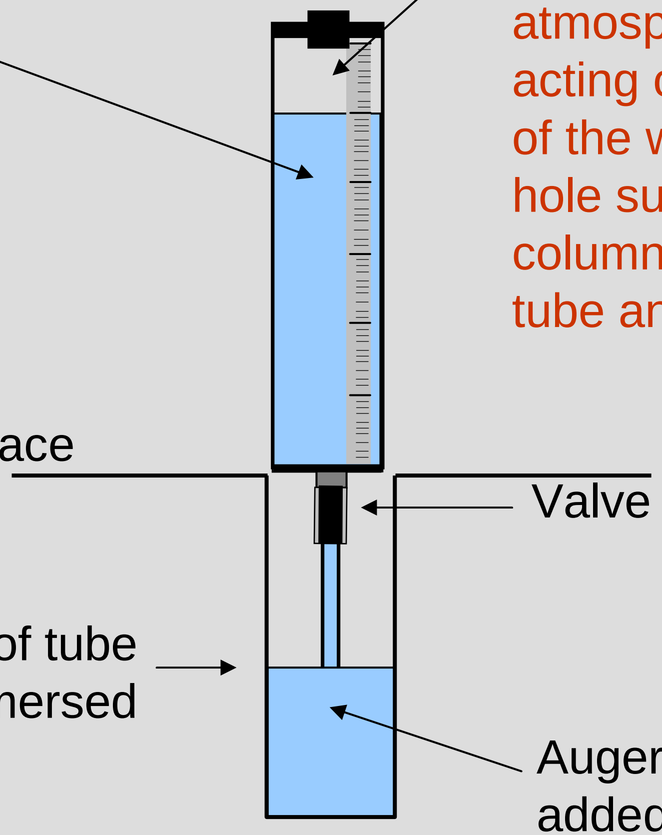
How the permeameter works

Like other constant head permeameters, the Cromer permeameter is essentially a graduated water reservoir and a delivery tube, which together operate on a very simple principle to maintain a constant depth of water in the test hole.

For permeability testing, the reservoir is fitted with a delivery tube, and the assembly is lowered vertically into a test hole (containing previously-added water) until the lower, open end of the tube is just immersed in the water….as follows.

How the permeameter works

Reservoir containing water. Rubber bung firmly in place at top. With (optional valve open and) tip of tube immersed, no water can leave the instrument.

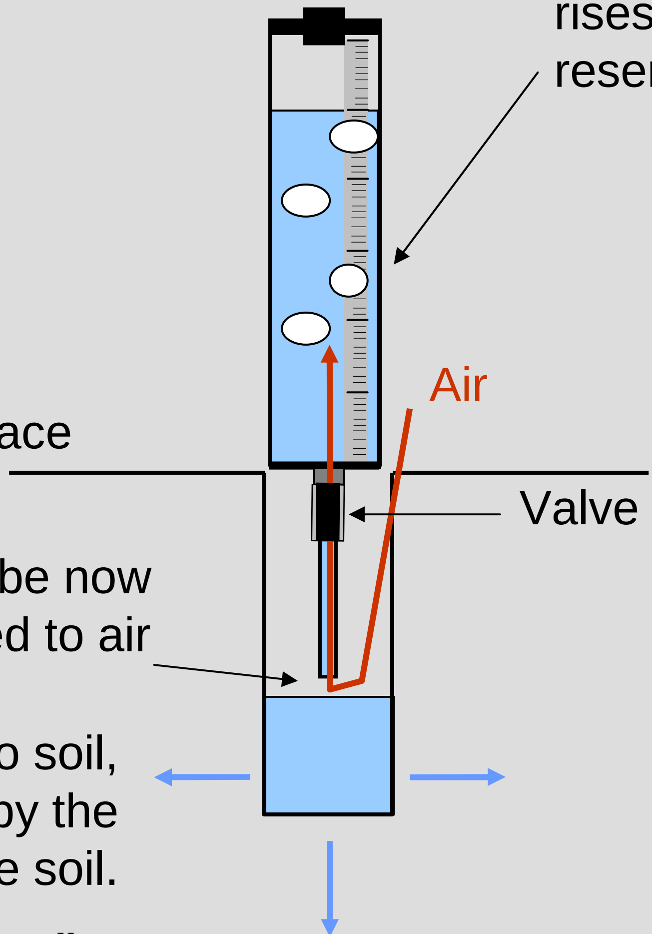


How the permeameter works

Water infiltrates into the soil, and the water level in the test hole drops.

Air enters the tip of the open delivery tube, and rises as bubbles in the reservoir

Ground surface



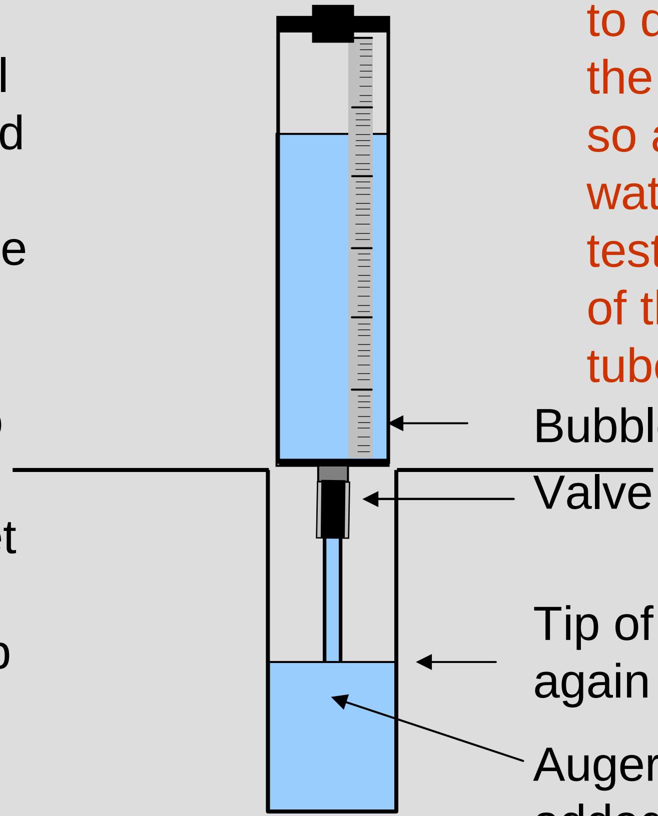
Valve (optional) open

Tip of tube now exposed to air

Infiltration of water into soil, at a rate determined by the permeability of the soil.

How the permeameter works

Air bubbles rising in reservoir displace an equal volume of water out the delivery tube into the test hole. Water level in reservoir therefore falls, and water level in test hole rises until the tip of the delivery tube is once again immersed. Bubbles then cease, and all activity (except infiltration into the soil) temporarily stops before starting again. The net effect is a ‘constant’ water level in the test hole, at the tip of the delivery tube.

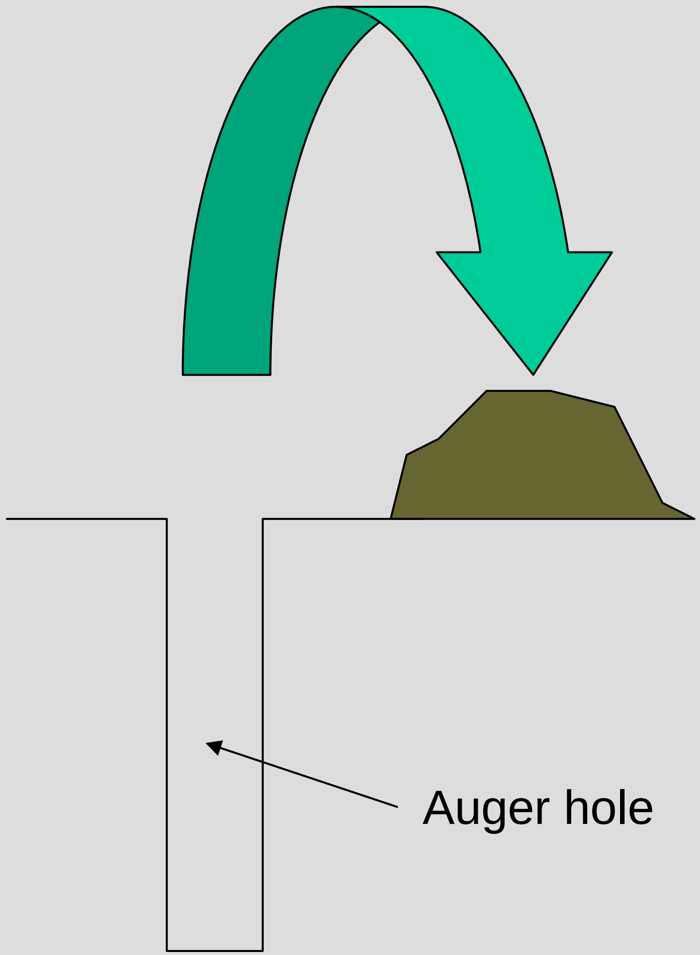


The sole purpose of the reservoir is to deliver water at the required rate so as to keep the water level in the test hole at the tip of the delivery tube.

Doing a permeability test

Step 1.
Select a site. Auger or dig one or more circular holes to establish the soil profile, and the interval you want to test.

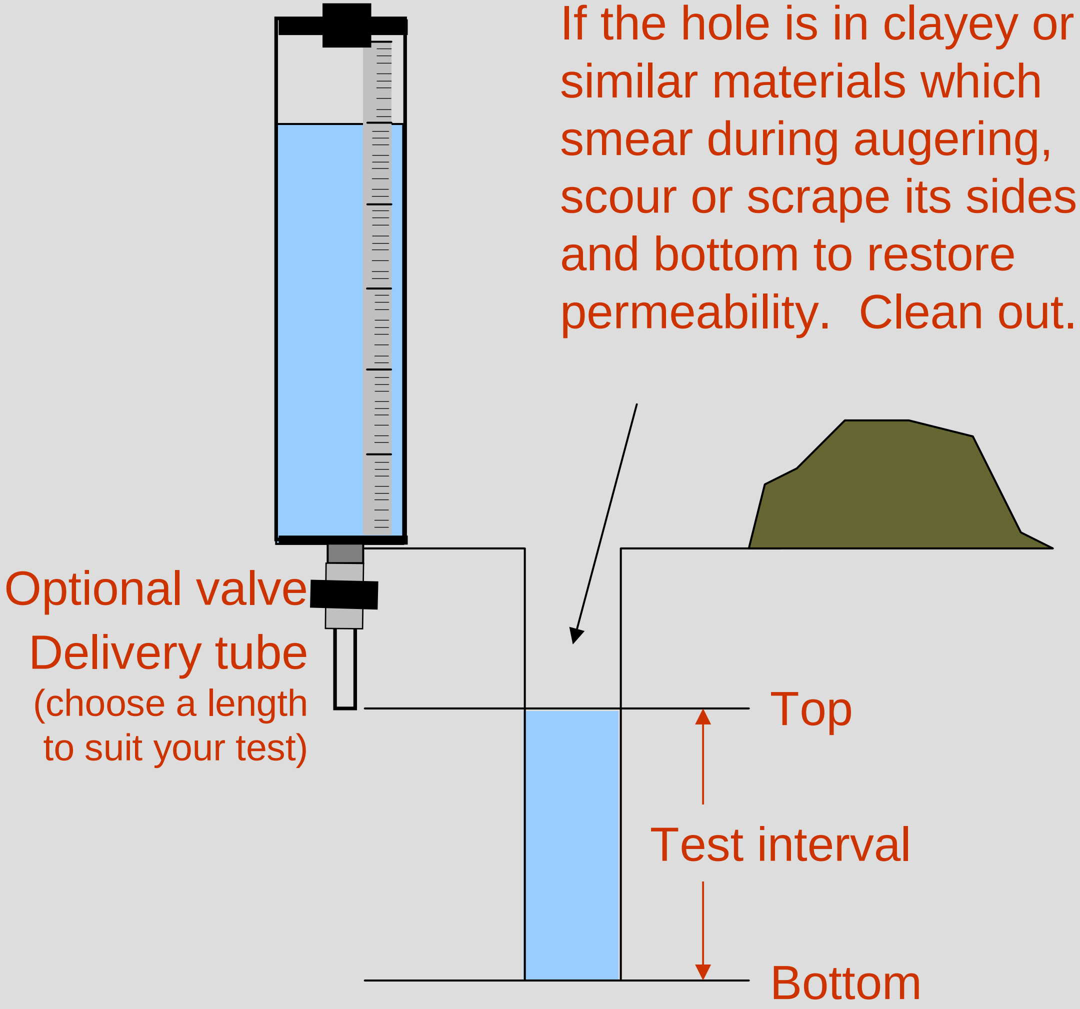
You may also need to log (describe the materials in) the holes, locate the holes with GPS coordinates and/or show them on a site sketch.



Doing a permeability test

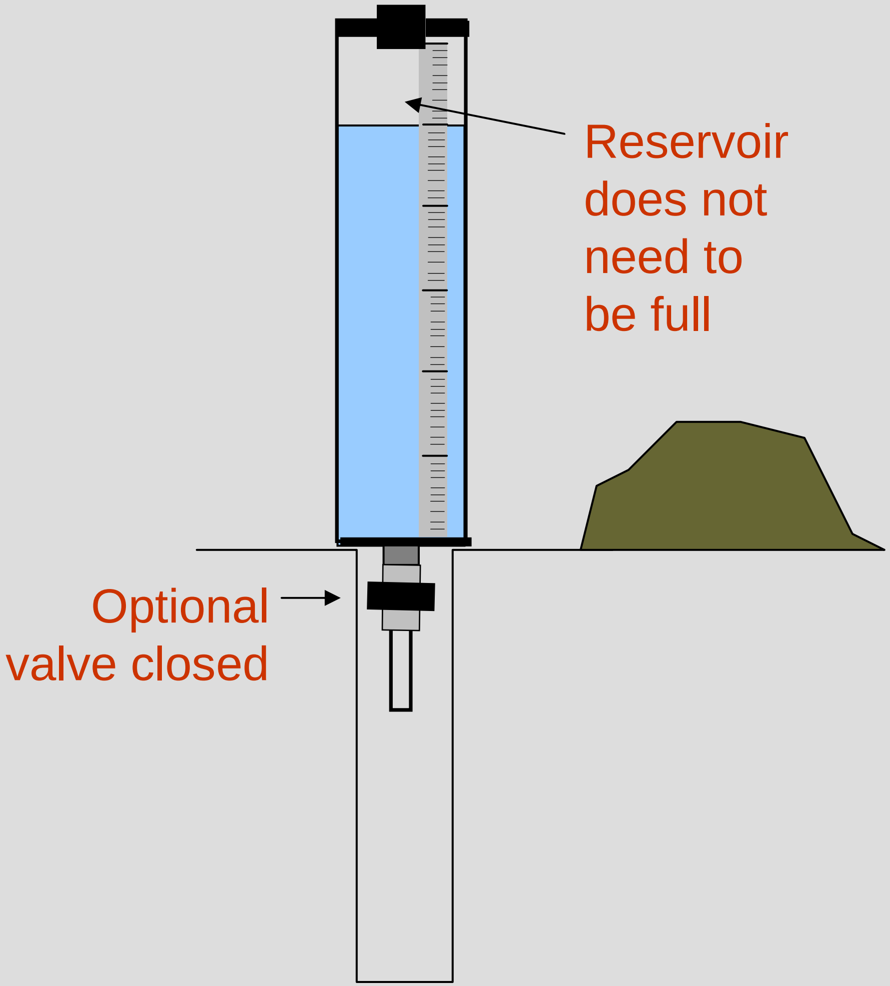
Step 2.
Select a hole. The <u>top</u> of the interval you test is determined by the combined length of the (optional) valve and delivery tube on the permeameter. The <u>bottom</u> is determined by the depth of the hole. Ideally, the test interval (i.e. depth of water) should be at least 3 times the hole diameter.

If the hole is in clayey or similar materials which smear during augering, scour or scrape its sides and bottom to restore permeability. Clean out.



Doing a permeability test

Step 3.
Screw the desired length of delivery tube to the base of the permeameter. Add test water to the instrument through the bung hole at top. (To do this more easily, stand the permeameter upright with your finger blocking the open end of the delivery tube, or close the optional valve.)
Make airtight by pushing the rubber bung firmly into place. The bung will fit easier if you wet it first.
Check instrument for leaks.
Lay it aside.

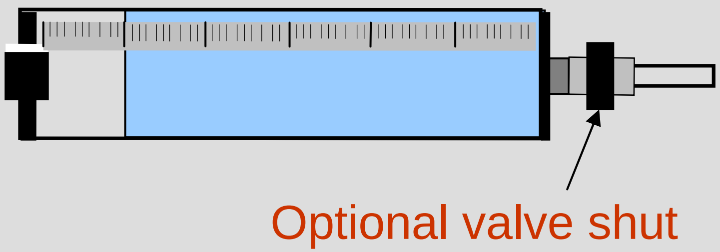


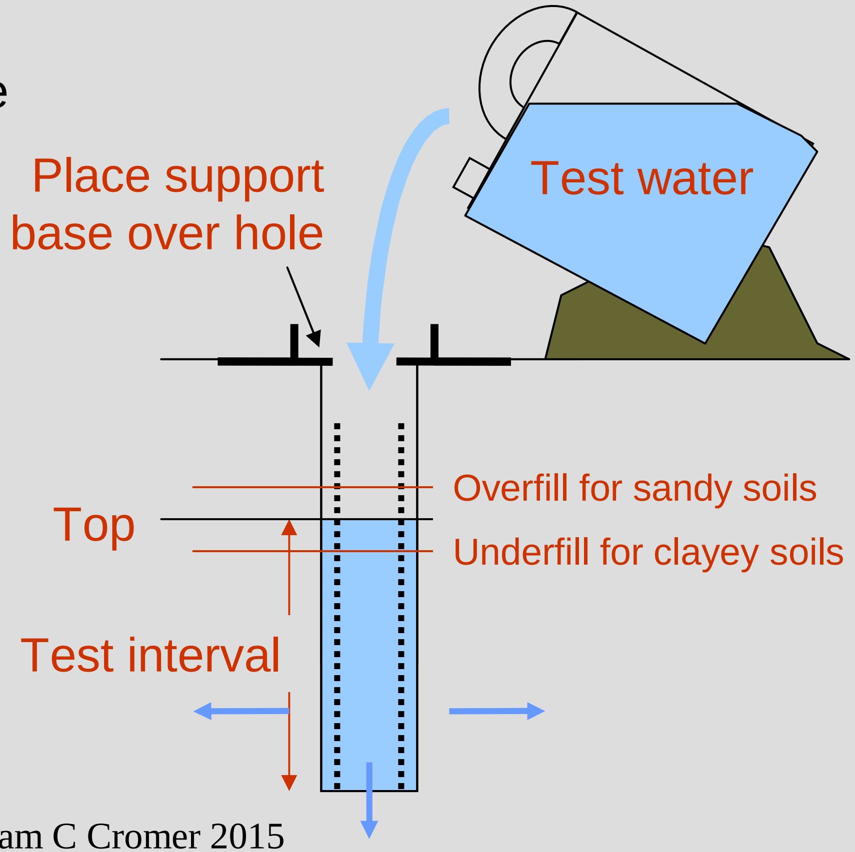
Doing a permeability test

Step 4.

Insert the slotted 50mm PVC screen into the hole (if required). Add water to the hole, to near the top of your test interval. Add the circular base to hold the instrument upright.

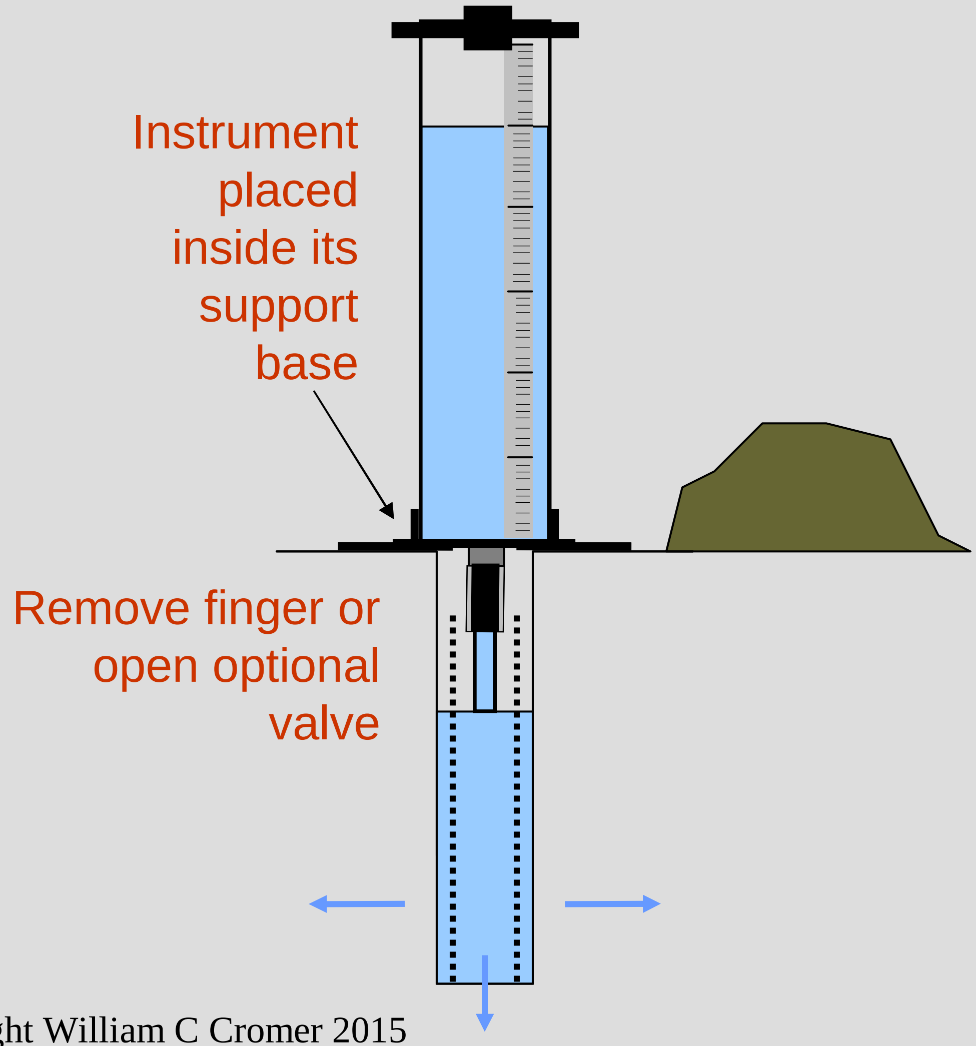
Until you insert the permeameter, you may need to keep topping the water level in the hole up as the water infiltrates the soil.





Doing a permeability test

Step 5.
Hold the permeameter vertically over the open hole, with your finger over the open end of the delivery tube, or, if you are using the valve supplied, <u>open it now</u>, and lower the instrument into the hole until the base of the reservoir rests in its support base on the ground.

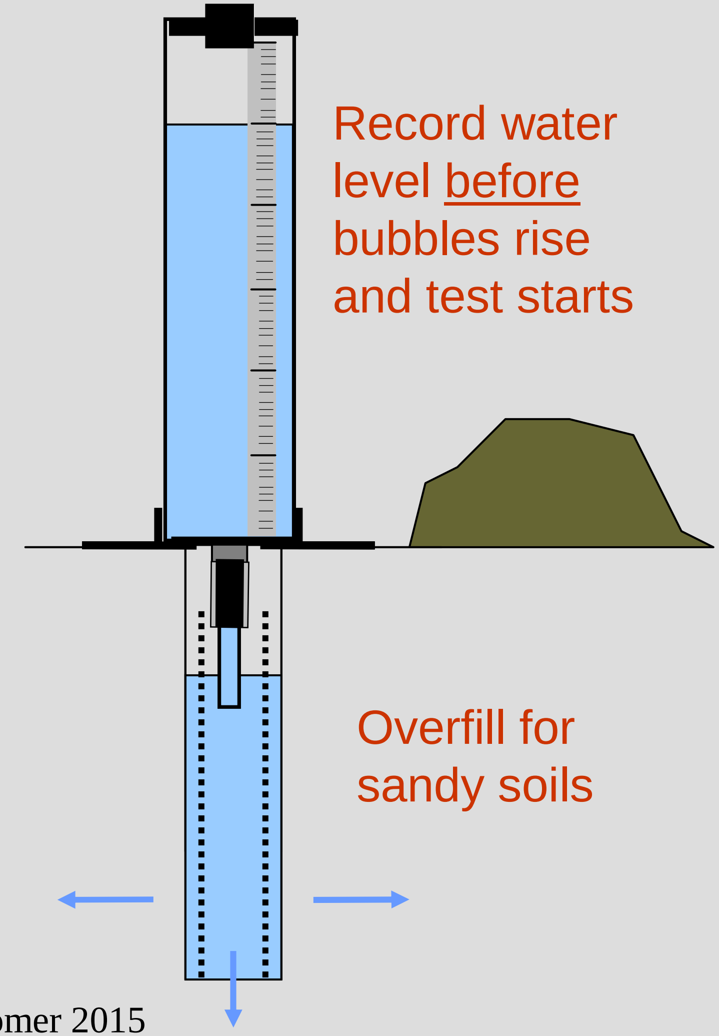


Doing a permeability test

Step 6.

<u>In high permeability soils.</u>

If you have slightly overfilled the hole with test water (because the soils are sandy or of high permeability), record the volume in the reservoir now. The test starts when the water level in the hole falls below the level of the tube, and bubbles <u>start</u> rising in the reservoir.

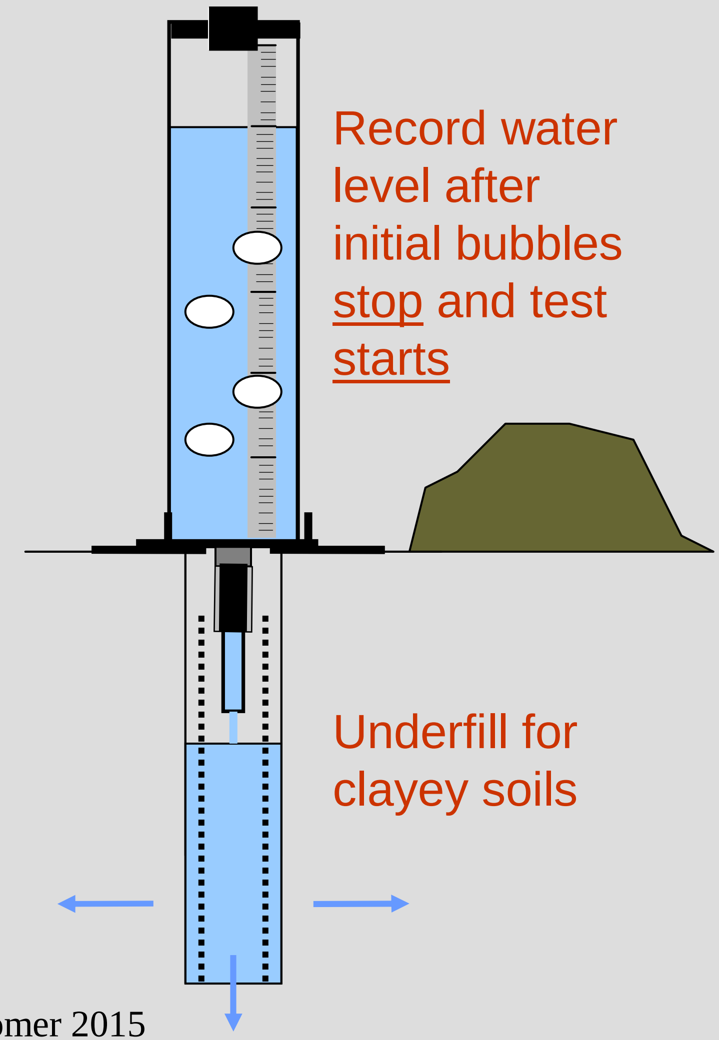


Doing a permeability test

Step 6 (continued).

<u>In low permeability soils.</u>

If you have slightly underfilled the hole with test water (because the soils are clayey or of low permeability), the test starts only when the water level in the hole rises to the level of the tube, and bubbles temporarily <u>stop</u> rising in the reservoir. Record the water level in the reservoir when bubbles temporarily <u>stop</u>.



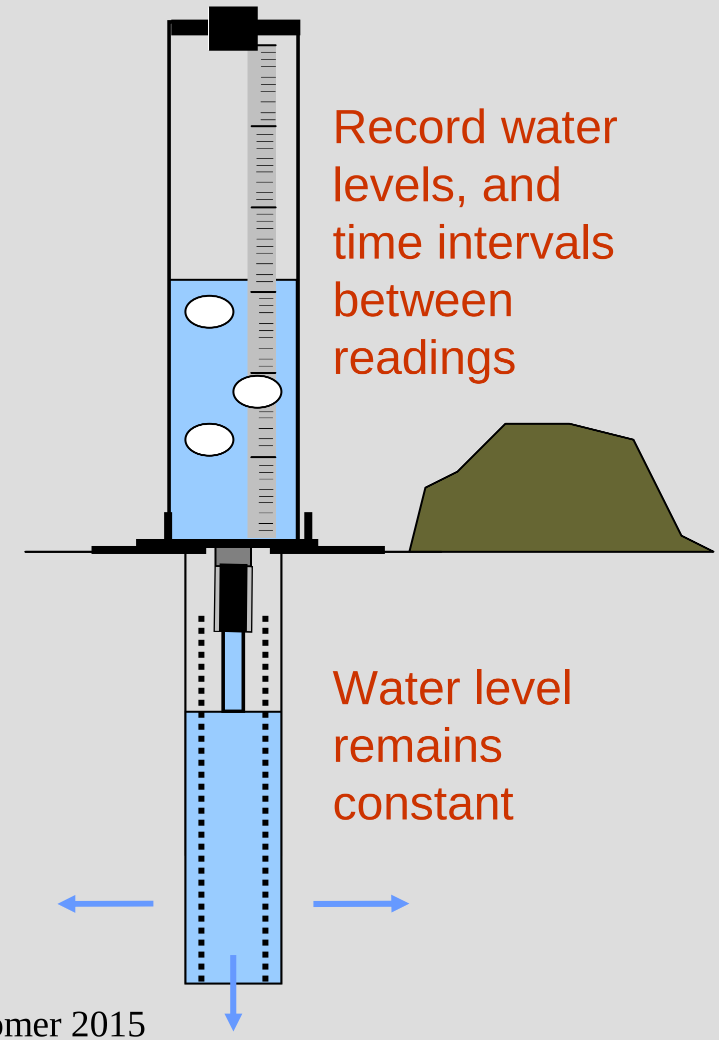
Doing a permeability test

Step 7.
Record the water level in the reservoir at various times. Record the time interval between readings.

For example, in <u>high</u> permeability soils, measure the level every minute or so, as required.

In <u>moderate</u> permeability soils, measure the water level every (say) 5 to 20 minutes.

In <u>low</u> permeability soils, measure the water level at longer intervals.



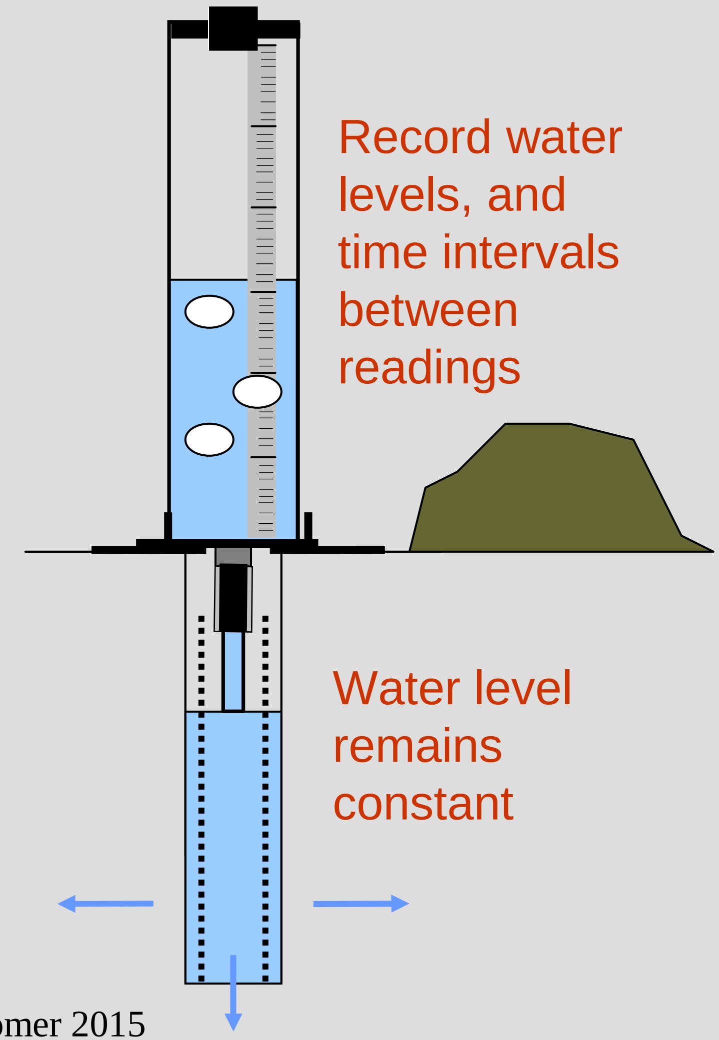
Doing a permeability test

Step 8.
As the test continues, track the rate of flow (L/min) from the instrument for different pairs of readings.

For example,

Water level at time t	= 4.95 L
Water level 2 mins. Later	= 4.55 L
Infiltration (flow) in 2 mins	= 0.4 L
Flow in 1 min	= 0.2 L

End the test when 2 or more successive flow rates do not differ by more than about 10%.



Doing a permeability test

Step 9.

You may use less than a litre of water testing low permeability materials, less than a reservoir full (about 4.5 L) in moderate permeability materials, and perhaps 10-15 L doing a test in high permeability materials.

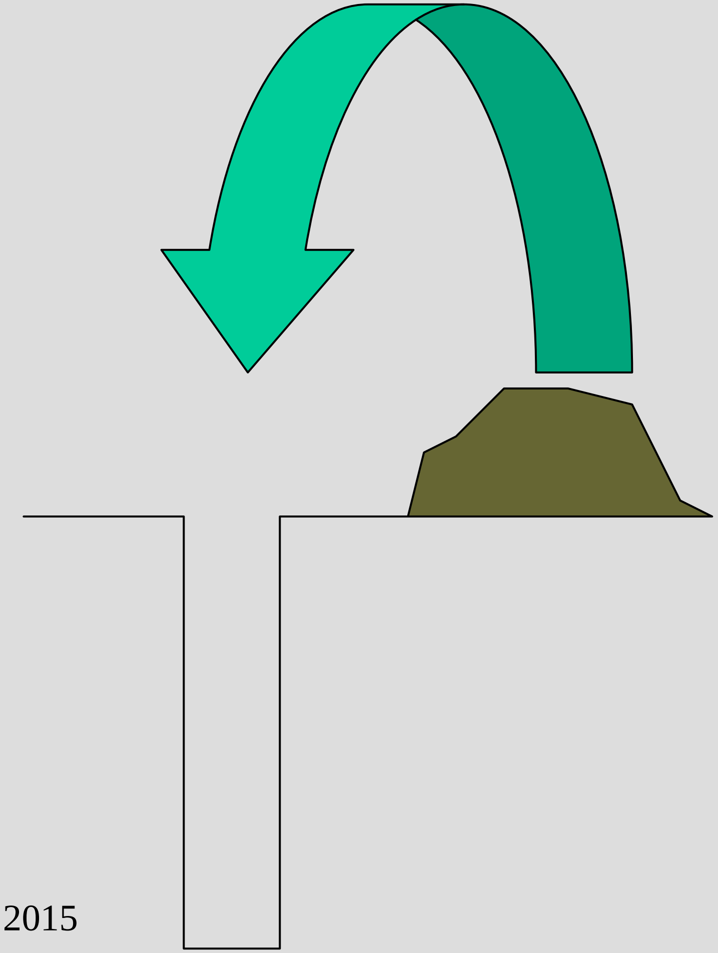
If you have to refill the instrument during a test, treat the refill as a separate test: ie pull out, turn (optional) valve off, pull out bung, refill instrument, replace bung, test for leaks, lay aside, top-up test hole (overfill), open valve, re-insert instrument, start readings. Continue readings to steady flow rate.

Doing a permeability test

Step 10.
Backfill the auger hole(s) tightly.

Open holes are dangerous to (the legs of) humans and animals.

Clean up the site.



Minimum recording of test results

You should record field results in a systematic manner.

The minimum information you require to calculate a permeability from a circular test hole is:

test hole diameter
depth of water in test hole
(steady) flow rate from instrument in L/min (which must be converted to cubic metres per day by multiplying by 1.44).

Defensible recording of field results

To be defensible, you should record more than the minimum information required.
This field sheet is a suggested example. It summarises two tests. It also allows you to graph the flow rate with time, to better see when steady-flow conditions are approached. Copy it from the hard or digital copy of the Instruction Manual supplied with the permeameter.

For more details of the test, you should add test hole depth, description of the materials in the hole, GPS grid coordinates of the hole, and site photographs

Sheet of

(Company name)
(Company address, etc.)

Permeability Field Test

ID ______

Project ______ **Location** ______

Test site description ______ **Tested by** ______

Constant head permeameter Instrument brand name ______ Reservoir volume (L) ______

Test hole geometry

	TEST 1	TEST 2		TEST 1	TEST 2
Hole depth (m)			Source of test water		
Hole diameter (mm)			Est. salinity of test water (mg/L)		
Depth to water (m)			Est. SAR of test water		
Depth int. tested (m)			Depth (m) below hole to imperm. layer		

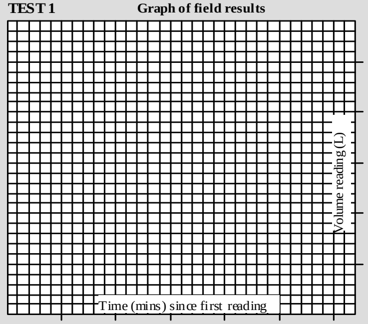
TEST 1 **Tested soil type** ______

Time (hr:m)	Time elapsed (mins)	Volume reading (L)	Volume infiltrated (L)	Infiltration rate (L/min)

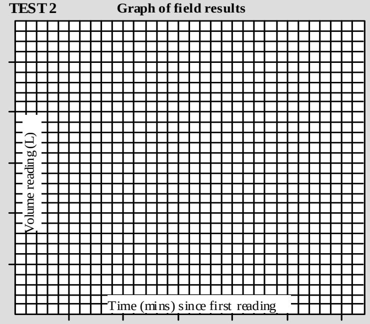
TEST 2 **Tested soil type** ______

Time (hr:m)	Time elapsed (mins)	Volume reading (L)	Volume infiltrated (L)	Infiltration rate (L/min)

TEST 1 **Graph of field results**



TEST 2 **Graph of field results**



Calculating permeability

To calculate permeability from constant head tests, the Instruction Manual uses two equations. The first is from Australian/New Zealand Standard 1547-2012 *On-site domestic wastewater management* (page 118). The second is from Australian Standard 1547-1994 *Disposal systems for effluent from domestic premises,* and Talsma and Hallam (1980). These and other references are listed at the end of this slide show.

These equations are approximations because they include simplifying assumptions about soil conditions and infiltration processes. Other equations are available, and these also provide approximate results.

Calculating permeability

This diagram shows the symbols used for the equations.

K = permeability of the soil

Q = rate of flow of water from the instrument (steady infiltration rate), equal to $(V_1 – V_2)/(t_2 - t_1)$ opposite.

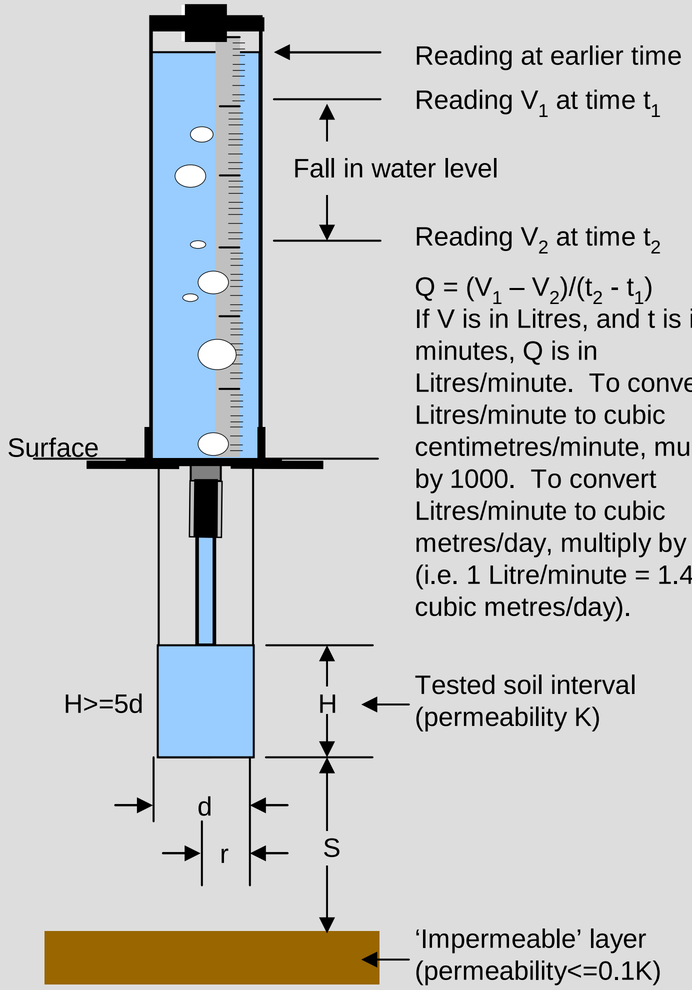
H = the depth of water (wetting) in the test hole

r = the radius of the test hole (= half diameter, d/2)

S = the depth to the impermeable layer

$\sinh^{-1}$ = the inverse hyperbolic sine function

π= Pi (i.e. 3.1416)



$Q = (V_1 – V_2)/(t_2 - t_1)$
If V is in Litres, and t is in minutes, Q is in Litres/minute. To convert Litres/minute to cubic centimetres/minute, multiply by 1000. To convert Litres/minute to cubic metres/day, multiply by 1.44 (i.e. 1 Litre/minute = 1.44 cubic metres/day).

Calculating permeability – Equation 1

Equation 1 is used in situations where the distance from the bottom of the test hole to an 'impermeable' layer is more than twice the depth of water in the hole (i.e. where S>2H in the previous slide):

$K = 4.4Q.\{0.5\sinh^{-1}(H/2r)-[(r/H)^2+0.25]^{0.5}+r/H\}/2\pi H^2$ (Equation 1)

If Q = L/day, and H and r are in metres, K is in metres/day.
If Q = cm^3*/min,and H and r are in cm, K is in cm/minute*.

The 'impermeable' layer should have a permeability less than one-tenth that of the soil being tested. You should establish whether such a layer exists at your test site before deciding whether to use Equation 1 or Equation 2.

Calculating permeability – Equation 2

Equation 2 is used in situations where the distance from the bottom of the test hole to an 'impermeable' layer is equal to or less than twice the depth of water in the hole (i.e. where $S<=2H$):

$K = 3Q.\ln(H/r)/\pi H(3H + 2S)$ (Equation 2)

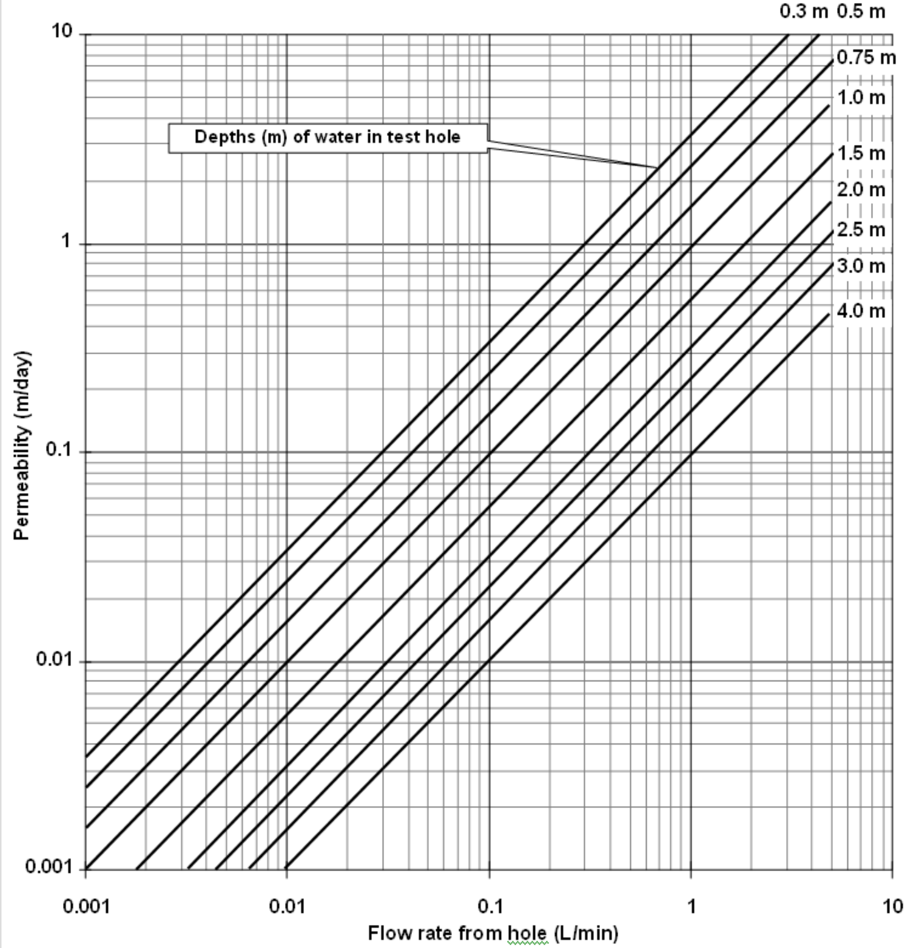
If Q = L/day, and H, r and S are in metres, K is in metres/day.
If Q = cm^3/min,and H, r and S are in cm, K is in cm/minute.

This equation should not be used if a <u>more</u> permeable layer exists beneath your surface layer.

Calculating permeability – nomogram

If you have used a circular, 120 mm diameter hole for your test, this nomogram can be used in the field or office to estimate permeability calculated from Equation 1 (but not Equation 2).

The nomogram is also in the Instruction Manual.



Permeability nomogram for various depths of water in a test hole (use only for circular, 120 mm diameter holes)

Calculating permeability – precision

Soil permeability can change substantially over very small distances, both horizontally and vertically. The Cromer Constant Head Field Permeameter has in-built imprecision (for example, you cannot read water levels more accurately than to about the nearest 0.05 L), and the equations you are using are approximations.

Therefore, don't report your calculated permeability to more significant figures than your data allow. For example, a reported field permeability of 0.0125 m/day is unjustified. Round it off to 0.013 m/day, or better still, 0.01 m/day. Similarly, 3.79 m/day should be rounded off to 4 m/day.

Generally, extra accuracy and precision are not needed.

Further reading

Australian Standard 1547-1994. *Disposal systems for effluent from domestic premises*. Standards Association of Australia.

Australian/New Zealand Standard 1547-2012. *On-site domestic wastewater management*. Standards Association of Australia.

Reynolds, W. D. and Elrick, D. E. (1983). A Reexamination of the Constant Head Well Permeameter Method for Measuring Saturated Hydraulic Conductivity above the Water Table. *Soil Science*, 136 (4) pp 250-268.

Reynolds, W. D., Elrick, D. E. and Clothier, B. E. (1985). The Constant Head Well Permeameter: Effect of Unsaturated Flow. *Soil Science*, 139 (2) pp 172-180.

Talsma, T. and Hallam, P. M (1980). Hydraulic Conductivity Measurement of Forest Catchments. *Australian Journal of Soil Research*, 30, pp 139-148.

Zangar, C. N. (1957). Theory and Problems of Water Percolation. *Engineering Monograph No. 8, Bureau of Reclamation, US Dept. of the Interior* (Denver, Colorado). 75 pp.

This is the last slide.

Right-click and select ‘End Show’ from the drop-down menu.