USER GUIDE

ETC PASK (CONSTANT HEAD WELL) PERMEAMETER FOR IN-SITU MEASUREMENT OF FIELD SATURATED HYDRAULIC CONDUCTIVITY OF SOILS

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1 INTRODUCTION AND BACKGROUND

Saturated hydraulic conductivity, Ks, is a measure of the "ease" with which water flows through a permeable material such as soil. The higher the Ks value, the greater the water flow rate for a given hydraulic gradient. In-situ methods that infiltrate the water into unsaturated soil do not measure Ks, but rather a reduced "field-saturated" hydraulic conductivity, Kfs, because of air entrapment during the infiltration process (Reynolds, 1993). As noted in Reynolds (1993) and elsewhere, Kfs can be less than or equal to half of Ks due to partial blocking of soil pores by air bubbles. In the design of on-site sewage disposal fields, Kfs is preferred over Ks because drainage through the soil should be designed to occur at less than complete soil saturation.

2 CONSTANT HEAD WELL PERMEAMETER

In-situ measurement of Kfs can be achieved using the "Constant Head Well Permeameter" (CHWP) method (Reynolds, 1993; Elrick and Reynolds, 1986). The CHWP method is based on the observation that when a constant height or "head" of water is ponded in a borehole or "well" augured into unsaturated soil, a "bulb" of *field-saturated* soil is gradually established around the base of the well (see Fig. 3 in Elrick et al., 1989 and associated discussion).

By "field saturated" we mean that the bulb in not truly saturated, but contains a certain amount of air that is entrapped or encapsulated by the infiltrating water (Constantz et al., 1988). As this field saturated bulb becomes established, the flow of water out of the well and into the soil approaches a ***quasi steady flow rate***. Once this quasi steady flow rate is attained, the Kfs of the soil surrounding the well can be determined using the flow rate, the radius of the well, and the head of ponded water in the well.

The CHWP method represents an improvement over previous borehole techniques (such as the Glover analysis) by addressing **all three components of borehole flow**, namely:

1) flow due to the hydrostatic pressure of the ponded water,
2) gravity-driven infiltration out through the base of the test hole, and
3) infiltration due to the capillary suction or "capillarity" of the surrounding unsaturated soil.

The *field saturated hydraulic conductivity*, Kfs, determined using the CHWP technique, is a much more scientifically and technically sound indicator of soil permeability than the outdated percolation test (PT). Kfs testing controls for variables that can substantially affect the PT such as: pit/borehole dimensions, depth of water ponding, soil capillary properties, and background soil moisture content at the time of the test.

2.1 Calculating Kfs

The calculations presented here are based on the work of W.D. Reynolds and D.E. Elrick formerly of the University of Guelph, Ontario, Canada. As with any measurement method, the assumptions and procedures involved with the CHWP technique should be understood before it is used as a field assessment procedure. Various well permeameter analyses have been developed, including single-head, two-head and multiple head procedures. In-depth reviews and descriptions of the CHWP method can be found in Elrick and Reynolds (1986, 1992a,b); Reynolds (1993); Bagarello et al., (1999); and elsewhere. This user guide outlines the "**extended single-head"** analysis described by Reynolds (2008) and Reynolds et al (1992).

The ETC Pask Permeameter is a convenient and easy to use apparatus for ponding a constant head of water in a well, and simultaneously measuring the flow into the soil. The key dimensions and attributes of the CHWP are represented by Figure 1. An appropriately placed air-inlet hole in the permeameter outflow tube establishes and maintains the desired water ponding head (H) in the well. Measuring the rate of fall (R) of the water level in the permeameter reservoir and reservoir cross-sectional area (X) allows determination of *quasi steady water flow rate* (Q) into the soil (i.e Q = XR). Kfs is then calculated using Equation 1 (Reynolds, 1993):

$$\mathbf{Kfs = CQ / [2\pi H^2 + C\pi a^2 + (2\pi H/\alpha^*)]} \qquad \textbf{(Eq. 1)}$$

where *C* is a *shape factor* selected from Figure 2, *a* is the well radius, and α^* is a parameter visually estimated from soil texture-structure (capillarity) categories in Table 2.1.

Table 2.1: Texture – Structure Categories for Visual Estimation of α^*

TEXTURE – STRUCTURE CATEGORY	Soil Capillarity Category	α^* (cm^{-1})
Coarse and gravelly sands; may also include some highly structured soils with large cracks and /or macropores.	Weak	0.36
Most structured and medium textured materials; including structured clayey and loamy soils, as well as unstructured medium single-grain sands. This category is generally the first choice for most soils.	Moderate	0.12
Porous materials that are both fine textured and massive; including unstructured clayey and silty soils, as well as very fine to fine structureless sandy materials.	Strong	0.04
Compacted, structureless, clayey materials such as landfill caps and liners, lacustrine or marine sediments.	Very Strong	0.01

Source: Adapted from Reynolds, W.D., (2008) and Reynolds et al (2015).

It should also be noted that, strictly speaking, the C-value curves in Figure 2 and the α^* values in Table 2.1 apply for soils that are at ***field capacity or dryer***, and when the wetting front from the well hole does not appear on the soil surface (Elrick and Reynolds, 1986).

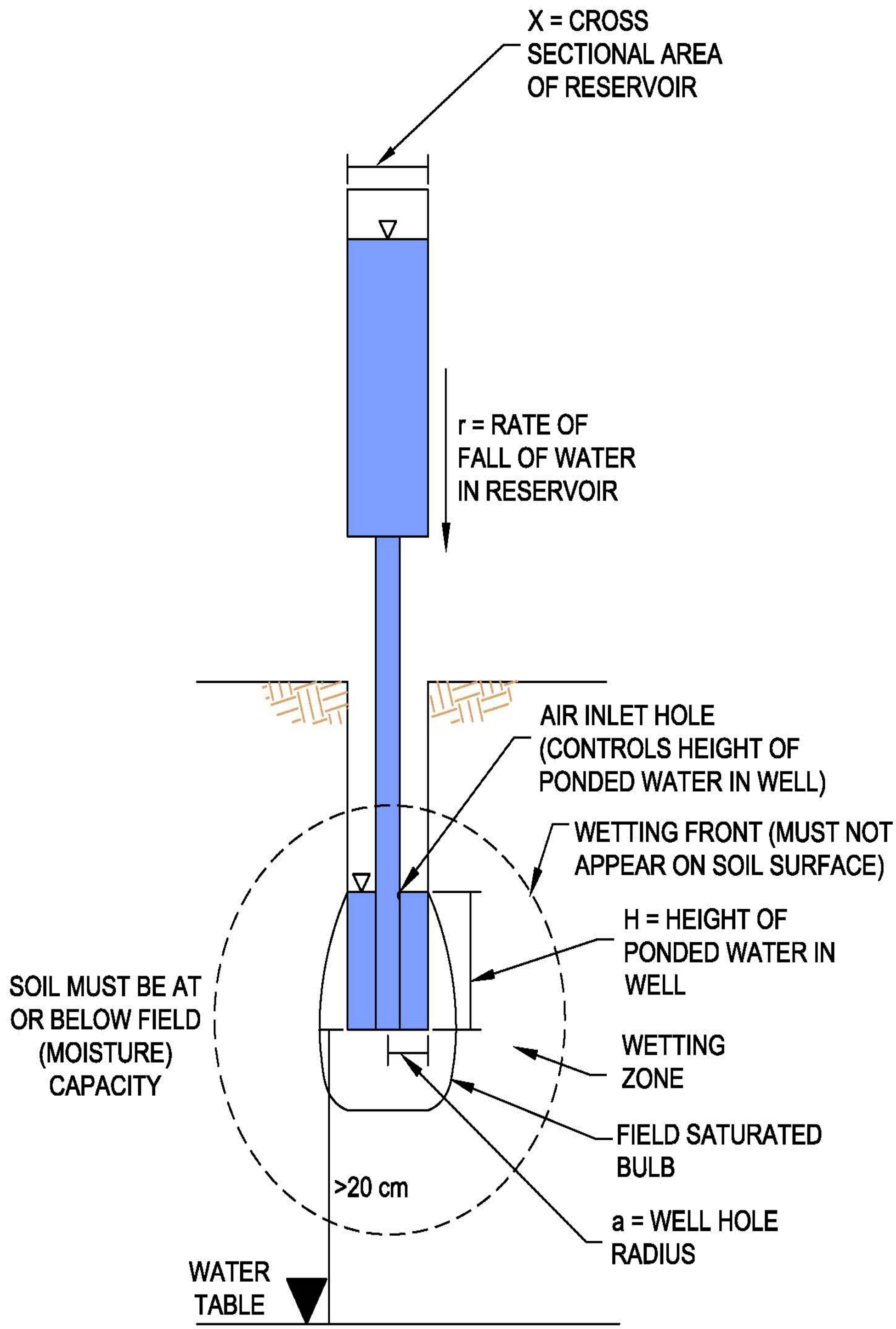

Figure 1: Constant Head Well Permeameter

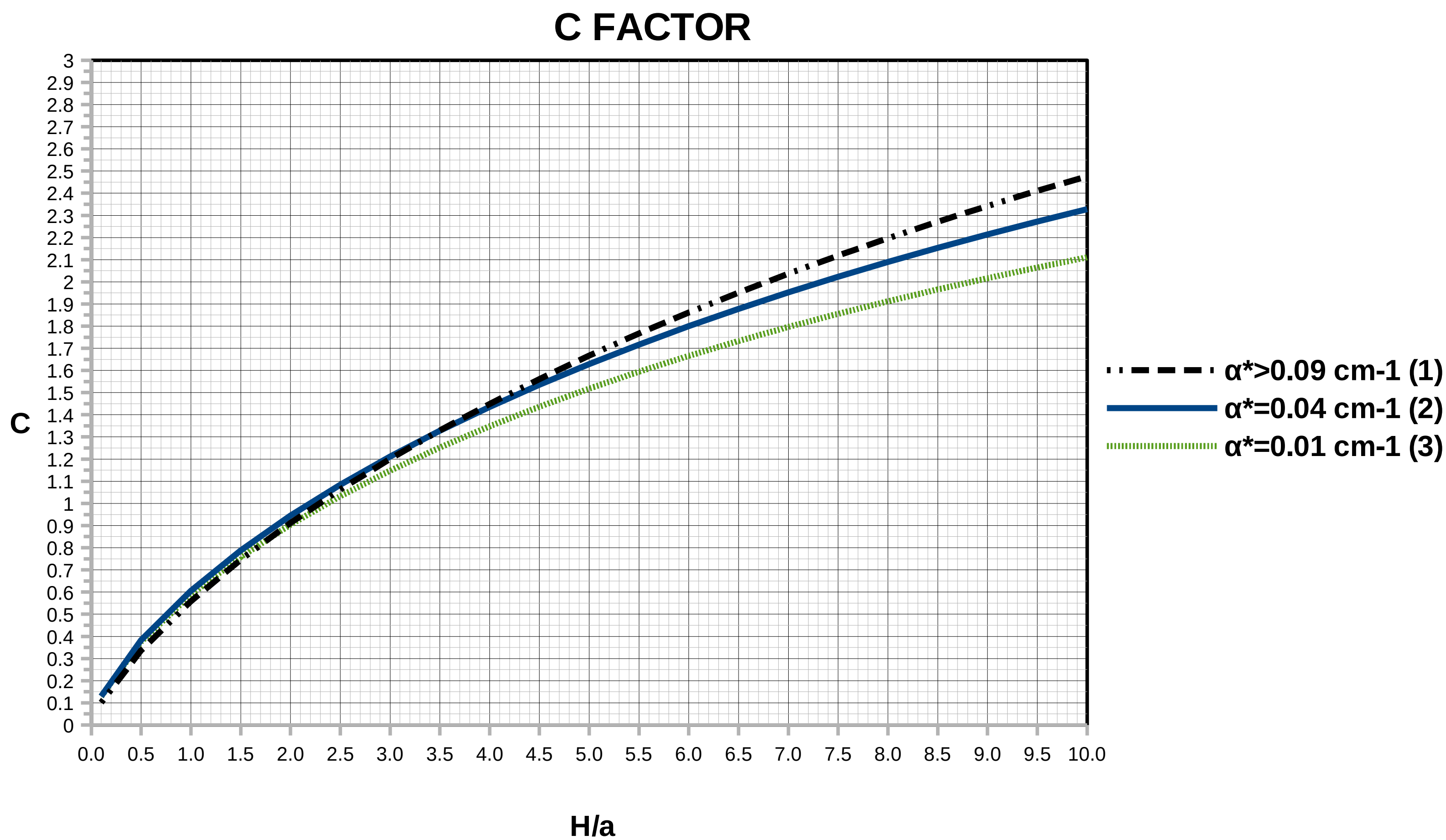

Figure 2: C Factor Chart, Adapted from Reynolds (2008)

2.2 Calculation Summary for Determining Kfs

2.2.1 Calculate Kfs from first principles

To calculate Kfs from first principles, you will need the following information:

a – well hole radius(cm)
H - height of air inlet hole from bottom of the test hole (cm, typically 15cm for ETC Pask Permeameters)
C - from C Factor graph (Figure 2) (unitless)
α^* - visually estimated using soil structure/texture categories in Table 2.1 (cm^{-1})
X - cross-sectional area of permeameter reservoir (cm^2)
R – quasi steady state (constant) rate of fall of water in permeameter reservoir (cm/min)

Calculate the rate of discharge into the well hole using Q=X R (cm^3/min); where

X = 53.46cm^2 for the ETC **Standard** Pask Permeameter
X = 12.80cm^2 for the ETC **Slow Soils** Pask Permeameter

Calculate Kfs using **Equation 1**:

$$\mathbf{Kfs = CQ / [2\pi H^2 + C\pi a^2 + (2\pi H/\alpha^*)]}$$

Refer to section 3.4.1 for a worked example showing how to calculate Kfs from first principles.

2.2.2 Determine Kfs using ETC Quick Field Reference Tables

Alternatively, *Quick Field Reference Tables* have been prepared by ETC for the specific permeameter characteristics and typical well hole diameter (8.3cm) produced by the 7cm (2-3/4”) AMS Riverside auger supplied with our kit. The tables give Kfs for various rates of fall (R) and α^* values. Alternative tables are provided for the Slow Soils Permeameter and a well hole diameter of 8.3cm.

CAUTION: The *Quick Field Reference Tables* should not be used with other constant head permeameters or when the well hole diameter is significantly different than indicated above. Calculate Kfs from first principles using Equation 1 instead.

Custom *Quick Field Reference Tables* may be ordered from Dynamic Monitors for alternative H values and well hole diameters.

Refer to section 3.4.2 for a worked example showing how to determine Kfs using the *Quick Field Reference Tables*.

2.3 Effects of Temperature on Results

The temperature of the water moving through the soil can have a significant effect on the measured Kfs because of the different viscosities of water at different temperatures. Warm water will flow through soil easier than cold water. Therefore, depending on test and design operating temperatures, it may be necessary to adjust the measured Kfs to get permeability that is more representative of operating conditions. This adjusted value (Ka) can be calculated by multiplying Kfs by a *temperature correction factor*.

The temperature correction factor is equal to the viscosity of water at the test conditions temperature divided by the viscosity of water for the expected system (e.g. septic disposal field or subsurface stormwater infiltration system) operating temperature.

Calculate the adjusted **Ka** value using Equation 2.

$$\mathbf{Ka = Kfs \times \mu_k/\mu_a} \qquad \textbf{(Eq. 2)}$$

where: Ka = adjusted permeability for design temperature conditions
Kfs = calculated permeability from the field test
μ_k = viscosity of water at the test conditions
μ_a = viscosity of water at the adjusted design temperature.

For on-site sewage systems in northern climates a design (operating) temperature of 4°C may be appropriate for sewage systems used year round. Table 2.2 provides the temperature correction factor for different water/soil test temperatures, assuming a system design temperature of 4°C. Alternative correction factors can be calculated for regions with different design or operating temperature requirements.

Table 2.2: Viscosity of water for temperature calculations.
Adapted from (Streeter and Wylie, 1975)

Water/soil Test Temperature °Celcius	Viscosity μ kg/m x s μ X 10^3	μ_k/μ_a For $\mu_a = 4^0$ C
4	1.560	1.000
5	1.519	0.974
6	1.469	0.942
7	1.419	0.910
8	1.369	0.878
9	1.319	0.846
10	1.308	0.838
11	1.268	0.813
12	1.228	0.787
13	1.188	0.762
14	1.148	0.736
15	1.140	0.731
16	1.110	0.712
17	1.080	0.692
18	1.040	0.667
19	1.010	0.647
20	1.005	0.644
21	0.975	0.625
22	0.945	0.606
23	0.915	0.587
24	0.885	0.567

If we were to assume that water and soil temperature down-slope of a septic disposal field were approximately 4°C in winter and the water/soil temperature was 20°C during the in situ permeability test, the value of Ka would be approximately equal to Kfs x 0.644. This difference may be within the design or other inherent factors of safety however the designer must be aware of this temperature effect and be sure that the system has adequate capacity under all operating conditions.

2.4 Potential Errors and How to Mitigate Them

One of the most important considerations, and potential sources of error, is not letting the test run long enough for the rate-of-fall to reach quasi **steady-state** conditions. As discussed in Section 3.3.4, typically quasi steady state flow can be considered to have been achieved after getting 3 to 5 consecutive rate-of-fall readings which are the same. Not waiting until steady state flow has been reached will typically result in **overestimation** of Kfs values.

Smearing and compaction from augering may also cause erroneous results. To avoid this, use a light touch when augering, and employ the "two-finger, two-turn rule" discussed in Section 3.3.3. The wire brush provided with the kit should also be used to brush the sides of the well hole and remove or scarify any smeared layer. Generally speaking, these errors will result in **under-estimation** of Kfs values.

As discussed in Section 3.3.2, wet (near-saturated) soils of all types are above ***field capacity*** and this may cause the Single-Head CHWP analysis to overestimate Kfs in fine-textured, structureless soils that are very wet (Reynolds, 2008, 2015). Practitioners should therefore be capable of recognizing that soil conditions are at, or drier than field capacity as a prerequisite to visually estimating α* to determine Kfs.

There is the potential for error due to **inappropriate selection of α***. Reynolds (2008) explained that the potential error due to improper selection of α* was not excessive and could be mitigated by using a ponded well height (H) that is as large as possible. Caution should be used not to make H too large, however, as this increases the likelihood of encountering **heterogeneity** such as layering, horizonation, cracks, worm holes, root channels, etc. If there were large variations in the soil profile such as a restrictive layer just below the hole or lenses of different soil textures throughout the tested range, the test may not provide representative results. To balance these two considerations, ETC has chosen a default well height of 15 cm for our permeameter, which seems to work well for most slow to moderately permeable soils. Alternative well heights to suit very fast or very slow soils can also be provided upon request.

The well hole should be as **cylindrical and have as flat a bottom as possible**. Small variations in hole diameter should not significantly affect the results (Twigg and Lilly, 1991, Reynolds, personal communication, 2015). Some manufacturers of other permeameters provide a *sizing auger* with their kit to facilitate creating a well hole with as flat a bottom as possible. However, Lilly (1991) recommends against the use of a sizing auger as it can increase soil smearing. The Riverside auger supplied with our kit has been found to produce a sufficiently flat bottomed well hole for most common applications (septic site assessments, stormwater system design).

The **temperature of the water in the permeameter** should be close to the ambient air temperature when conducting the test. If not, as the water temperature increases or decreases, the rate of water drop in the permeameter may vary and the rate will not become constant.

Several permeameter tests should be conducted at a site to be sure that the test results are representative of the true soil conditions. The examination of test pits in the area of the permeameter tests, plus the experience and judgment of the person conducting the test are critical to ensure that any results which are not consistent with the overall soil texture and structure are considered to be suspect and/or are rejected.

3 PASK CONSTANT HEAD PERMEAMETER

3.1 Background

There are several different constant head well permeameters. Although they are all capable of measuring Kfs, each have specific advantages and limitations which can affect their usefulness and suitability for a particular application.

Only the ETC "PASK" permeameter is described in this guide. This permeameter was suggested for use in Nova Scotia in the 1980's by David Pask of the Nova Scotia Department of Environment. It became popular in the Maritime provinces of Canada and beyond for on-site sewage disposal assessment and design/selection. The permeameter is easy to use and provides reliable results when used under appropriate conditions. The current components of the ETC Standard Pask Permeameter Kit are shown in Figure 3.

Figure 3: Components of ETC Pask Permeameter Kits showing Standard Permeameter (left) and Slow Soils Permeameter (right).

3.2 Verify Integrity of Permeameter Seals

All ETC Pask Permeameters are tested at our facility, to verify they are water tight, before they are shipped. Dropping or rough handling of the permeameter could result in a crack in the reservoirs or seals causing leakage and erroneous test results. Therefore, it is important that your Permeameter be checked immediately upon receiving it, and thereafter on a periodic basis to ensure it is water tight. The procedure recommended by ETC can be found in Appendix B.

3.3 Pask Permeameter Test Method

Following are the steps to be employed when conducting a test with the ETC Pask Constant Head Permeameter.

3.3.1 Well Hole Location and Weather Conditions

Care should be taken to locate the hole(s) in locations that will most closely represent the Kfs values of the area in question. Attention should be paid to any soil condition that may cause an unrepresentative value of Kfs such as the presence of excessive worms or rodent activity, roots, clay or gravel lenses or soil cracks.

Strong or gusting winds can result in inaccurate readings from movement of the permeameter and/or movement of the water within the permeameter. If the permeameter can not be sufficiently stabilized, the test should be carried out another day (Elrick and Reynolds. 1992, Reynolds, 2008).

3.3.2 Soil Moisture Conditions

As mentioned previously in Section 2.1, as long as the soil moisture condition is less than its ***field capacity***, α^* can be selected from one of four general capillarity categories (via Table 2.1) which are primarily related to the soil structure and texture. One working definition of "field capacity" (Reynolds et al, 2015) is "the water content that exists in the soil once drainage stops after a soaking (saturating) rain". Cessation of soil drainage corresponds roughly with the time at which tile drains stop flowing after a rain event. As a rough "rule of thumb", soils at field capacity water content or drier do not compress under foot and they tend to crumble (rather than remold or smear) when worked in the hand.

The field capacity soil water content usually corresponds to the *pore water pressure head* (or *matric potential*) of $\psi = -1$ m; and it is the pore water pressure head that actually imparts soil capillarity, not the soil water content. Field measurement of near-surface ψ using a tensiometer (e.g. Quickdraw tensiometer, Soilmoisture Equipment Corp., CA) should be used if practitioners are not confident in their ability to assess the field capacity condition based on visual and textural indicators alone.

3.3.3 Well Hole Preparation

1. Using the Riverside/Bucket auger provided with the kit, excavate a well hole to the desired depth. Note: If you are planning to use the *ETC Quick Field Reference Tables* supplied with your kit, ensure that the well hole diameter produced by your auger is similar to what is indicated in the tables. The top layer of soil may be removed with a shovel or excavator before using the auger to complete the hole. Ensure the permeameter will rest on the bottom of the well hole, and not be suspended from the ground surface (i.e. Figure 4). Take care to not remove too much soil above the hole however, as it is important that the *wetting front* does not appear at the ground surface during the test.

2. The auger may smear the sides of the hole, particularly if the soil is fine textured and moist to wet. Smearing will usually result in an erroneous (lower) field saturated hydraulic conductivity (Kfs). *Sizing augers* (distributed with some permeameter kits made by others) should not be used, as it can make the smearing worse (Twigg and Lilly, 1991).

3. The "two finger method / two turn rule" is recommended to minimize the potential for smearing and compaction. It is described by Reynolds (2008) as follows:

   "once the top of the measurement zone has been reached, use only two fingers on each hand to apply downward pressure on the auger (ie. the weight of the auger applies most of the pressure), and make only two complete turns of the auger before emptying it out."

4. The bottom of the well should be at least 20 cm above the water table or capillary fringe (Figure 1) to prevent the water table from entering the well (Reynolds, 2008). If groundwater appears to be entering the well hole from the walls of the well, then the constant head method of testing may not be appropriate for this situation (Amoozegar A, Warrick AW. 1986).

5. Inspect well for smearing within the measurement zone using a flashlight. If smearing is present (soil generally appears smooth and polished), use the twisted stiff wire brush provided to remove it. Do not "over-brush" the hole. If removal of the smeared surfaces results in an appreciable increase in the size of the well hole, the new diameter should be measured and used in the calculations (Reynolds, 2008).

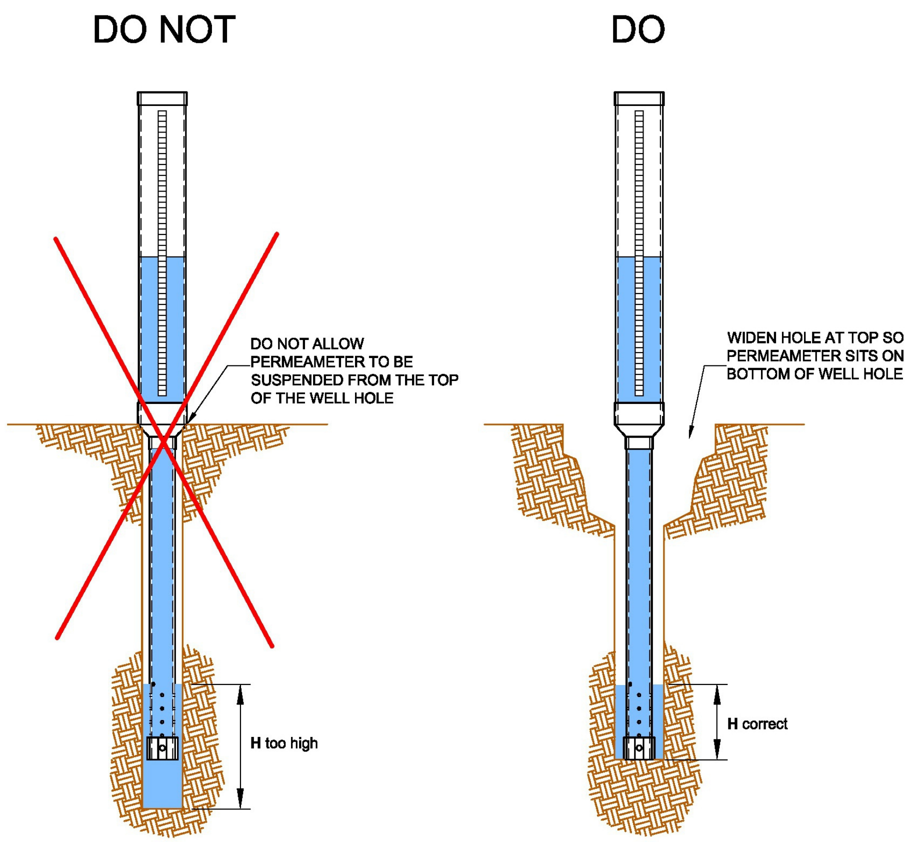

Figure 4: Proper Installation of the Pask Permeameter

3.3.4 Water Dispersal from the Permeameter

1. Fill the permeameter with water and apply the ABS cap so that the spring clip button locks it in place. The distance from the bottom of the cap to the air inlet hole should be exactly 15cm.

2. Place the support screen, if one is being used, on the bottom of the well hole.

3. Invert the permeameter into the hole, <u>ensuring that it rests on the bottom of the hole</u>. Carefully lean the permeameter against the side of the well hole so that it is stable and will not shift during the test. It should be as straight as possible, but it is not necessary for the permeameter to be perfectly vertical during the test. It is more important for the permeameter to be stable, so it will not shift once you start taking readings.

4. Water will initially flow out of the permeameter reservoir until the head of water in the well reaches the level of the air inlet hole. With some soil conditions, this initial rapid flow can cause "slaking" of the side walls of the well hole into the water. This may be

prevented by using a *well screen* or by backfilling around the lower tube of the permeameter with clean pea gravel (Lilly 1994, p75).

5. Allow the flow out of the permeameter to reach equilibrium (approach a constant, *quasi "steady state"* flow rate). Most medium permeability soils will reach quasi steady state flow conditions within 30 minutes to an hour. However, this can take as little as a few minutes in highly permeable materials to several hours in very slowly permeable soils. Monitor the reservoir water level at a reasonably consistent timing interval **until the rate of fall becomes relatively constant**. Typically quasi steady state flow can be considered to have been achieved after getting 3 to 5 consecutive rate of fall readings which are the same.

6. Record the value for the "steady state" rate of fall on the Field Permeability Test Sheet.

7. Use the table of soil structure and texture categories (Table 2.1) to estimate an appropriate α^* value for the soil zone tested.

8. Determine the *field saturated hydraulic conductivity* (Kfs) from the *ETC Quick Field Reference Tables*, or from first principles by using the formulas provided in this guide.

9. Apply a temperature correction to Kfs if deemed appropriate (see Section 2.3).

3.3.5 Care and Cleaning of End Cap and Spring Clip

Flush the lower part of the tube, end cap and spring clip with clean water upon completion of each test. This will maintain smooth operation, and prevent the cap or clip from sticking due to soil particles becoming lodged between the parts. We recommend flushing the cap and tube in the stream of water as it flows from the permeameter when emptying it.

3.3.6 Testing Imported Septic Fill Materials

The ETC Pask Permeameter can also be used to determine Kfs of built up beds of septic sand and other imported fill materials. Compliance or quality assurance testing can be carried out at the construction site, or in a properly prepared *test pad* of fill constructed at the pit or stockpile location for the fill. A suggested procedure for constructing a test pad is described in the ***CAN CSA B65-12 Installation code for decentralized wastewater systems*** (Canadian Standards Association, 2012) and is summarized as follows:

- Build a representative "test pad" of fill having a minimum area of 3m x 3m (10ft x 10ft)
- Test pad should have a minimum thickness of 900mm (3ft), constructed using maximum 150mm (6inch) thick layers, lightly compacted to a density that approximates that of the completed raised bed of septic fill.
- The bottom of the well should be deep enough so that the wetting front does not appear on the surface of the fill during the test, but also shallow enough so the *field saturated bulb* does not reach the underlying native soil below the fill. (ETC Note: We suggest providing at least 30cm (12") of fill below the bottom of the well hole.)

3.4 Example Problem for Calculation of Kfs

3.4.1 Calculate Kfs from first principles using Equation 1.

The soil type as determined from examination of a test pit near to the permeability test location is a *sandy loam* with a *weak blocky structure*. Based on this assessment, from Table 2.1, we select:

$\alpha^* = 0.12\ \text{cm}^{-1}$

From the field permeameter test, the quasi steady state rate of fall (R) was determined to be:

R = 0.20 cm/min

Using the auger supplied with the ETC Pask Permeameter Kit, the well hole diameter will be approximately 8.3 cm, therefore, the well hole radius, a = 4.15 cm.

For the ETC Standard Pask Permeameter:

X = Reservoir cross sectional area = 53.46 cm^2 (inside diameter is 8.25 cm)
H = Height of constant head in well=15 cm (from bottom of plug to air inlet hole)

Calculating:

H/a = 15/4.15 = 3.61

Therefore, from Figure 2 we can determine that:

C = 1.36 (for $\alpha^* = 0.12\ \text{cm}^{-1}$ use line 1 in Figure 2)

Calculating:

Q = XR = 53.46 x 0.20 = 10.69 cm^3/min

Calculate Kfs using Equation 1:

$$Kfs = CQ / [2\pi H^2 + C\pi a^2 + (2\pi H/\alpha^*)]$$

Where formula constants are grouped and named as “A” and “B”:

$$A = 2\pi H^2/C + \pi a^2 \qquad B = 2\pi H/C$$

Therefore, to calculate the field saturated hydraulic conductivity:

$$Kfs = Q/(A + B/\alpha^*)$$

Calculating:

$$A = (2\pi 15^2)/1.36 + \pi 4.15^2 = 1093.60\text{cm}^2$$

$$B = (2\pi 15)/1.36 = 69.30\text{cm}^2$$

Finally calculating:

$$Kfs = Q/(A + (B/\alpha^*)$$
$$Kfs = 10.69/(1093.60+69.30/0.12) \text{ cm/min}$$
$$Kfs = 6.3 \times 10^{-3} \text{ cm/min}$$
$$Kfs = 1.1\text{x}10^{-6} \text{ m/sec}$$

3.4.2 Determine Kfs from ETC Quick Field Reference Tables

Using the table for α^* =0.12 cm^{-1}, pick the Kfs value which corresponds to a rate of fall R = 0.20cm/min. The Kfs value is 1.1E-06 m/sec = 1.1 x 10^{-6} m/sec.

3.4.3 Temperature Correction

Assume that the soil and water temperature at time of testing in the example above was 10° C. If the septic system is to operate during the winter and the design winter soil/effluent temperature is anticipated to be 4° C, then the temperature corrected permeability would be calculated using equation 2 as follows:

$$Ka = Kfs \times \mu_k/\mu_a$$

where: Ka = corrected permeability adjusted for design temperature conditions
Kfs = the calculated permeability from the field test
μ_k = the viscosity of water at the test conditions (Table 2.2)
μ_a = the viscosity of water at the adjusted design temperature (Table 2.2)

Therefore:

μ_k= 1.308 at 10 °C
μ_a= 1.56 at 4 °C

So: μ_k/μ_a = 0.838 (Table 2.2)

Ka = 1.1 x 10^{-6} m/sec x 0.838

Ka = 8.9 x 10^{-7} m/sec

Therefore, it would be more conservative to use the temperature corrected value (Kfs = 8.9 x 10^{-7} m/sec) for septic system design purposes.

3.5 Relationship of Kfs to Percolation Time

The percolation test (PT) rate of fall or "Perc Time" is still used in many jurisdictions to determine suitability for onsite sewage disposal or for sizing of soil absorption systems (drainfields). It has been recognized for some time, however, that PT is less than ideal because it is not just a function of soil permeability, but also a function of test conditions.

The field saturated hydraulic conductivity, Kfs, determined using the CHWP technique, is a much more scientifically and technically sound indicator of soil permeability than the PT. Kfs testing controls for variables that can substantially affect the PT such as pit/borehole dimensions, depth of water ponding, soil capillary properties, and background soil moisture content at the time of the test.

Various correlations between Perc Time (PT) and field-saturated hydraulic conductivity (Kfs) have been proposed. Reynolds et al (2015) analysed PT versus Kfs correlations from Virginia, Georgia, Connecticut, and Ontario. None of the correlations were found to be generally applicable, accurate or scientifically defensible, in part because they did not completely describe the factors affecting PT and Kfs.

An accurate and physically based analytical expression relating PT to Kfs for cylindrical test holes was proposed (Reynolds, 2015 and Reynolds et al, 2015) from which usable PT versus Kfs relationships are now possible. A procedure has been described which shows how to determine PT from Kfs using the single-ponded height CHWP method. The reader should consult Reynolds et al (2015) for a detailed discussion of the factors and applicability of the newly developed PT to Kfs relationship. A summary of a simplified procedure to determine PT from Kfs which is applicable to the current ETC Pask Permeameter kit is outlined below.

Step 1: Determine Kfs and α^* using the Single-Head method outlined in this user guide.

Step 2: Determine the appropriate PT to Kfs *conversion factor*, ***m***, from Table 3.1 on the next page.

Step 3: Determine the "equivalent" PT that corresponds to the H, d (a), α^* and Kfs values, using the relationship, **PT = m/Kfs**, where Kfs is in meters/sec.

The calculated PT value is referred to as "equivalent" because borehole water level is held constant (at H) by the CHWP, thereby preventing direct measurement of PT = $\Delta t/\Delta H$.

Table 3.1: Conversion factor, *m*, relating Perc Time (PT) to Kfs for constant head, H=15.0cm and well hole diameter, d=8.3cm. PT=m/Kfs, where Kfs is in meters/sec.

Constant Head, H = **15.0** cm
Ave. Well Hole Diameter, d = **8.3** cm

Capillarity Category	Representative α* (cm-1)	m (for PT in min/cm)	m (for PT in min/inch)
Negligible	1.0	7.74E-06	1.97E-05
Weak	0.36	7.00E-06	1.78E-05
Moderate	0.12	5.39E-06	1.37E-05
Strong	0.04	3.18E-06	8.07E-06
Very Strong	0.01	1.05E-06	2.68E-06

CAUTION: It must be emphasized that Table 3.1 only applies to the well characteristics indicated. Refer to our web site (DynamicMonitors.com) for conversion tables applicable for other auger/well hole sizes and constant heads, or contact us to order custom tables.

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APPENDIX A

Field Permeability Test Example

Example Field Permeability Test Data Sheet

FIELD PERMEABILITY TEST EXAMPLE

You have excavated a test pit and logged the data as shown in the following table.

Depth below the root mat (cm)	Soil Description
0 - 30	Loamy Sand, loose, dry
30 - 90	Loam, compact, moderate blocky structure
90 - 120	Loam, very dense, weak blocky structure
120 - 180	Clay loam, massive

You decide to do a field permeability test at a depth of 60cm with your Pask Permeameter in the middle of the compact loam layer.

The most appropriate α^* value for *Loam, compact, and moderate blocky structure* would be $\boldsymbol{\alpha^* = 0.12\ \mathrm{cm}^{-1}}$.

The data recorded during the test are shown in the table below.

FIELD PERMEABILITY TEST # ____1____

D – reservoir diameter (cm)	8.25	**Soil Texture**	Loam
d – well hole diameter (cm)	8.3	**Soil Structure**	Moderate Blocky
H – height of water in well (cm)	15	**α* (cm-1)**	0.12
Depth below ground surface	60 cm	**C – Factor**	1.36

TIME (min)	(1) CHANGE IN TIME (min)	RESERVOIR WATER LEVEL (WL) (cm)	(2) CHANGE IN WL (cm)	(2) ÷ (1) RATE OF FALL (R) (cm/min)
0	-	**80.9**	-	-
6	6	**60.5**	20.4	3.4
12	6	**42.5**	18.0	3.0
15	3	**34.7**	7.8	2.6
19	4	**26.7**	8.0	2.0
22	3	**21**	5.7	1.9
30	8	**5**	16.0	2.0

The last three readings have stabilized (approached steady state). A rate of fall value of **R = 1.9 cm/min** is selected and the quick reference table for $\boldsymbol{\alpha^* = 0.12\ \mathrm{cm}^{-1}}$ should be used. The field saturated hydraulic conductivity Kfs = 1.0E-05 m/sec = 1.0×10^{-5} m/sec.

Engineering Technologies Canada Ltd.

OWNER'S NAME: ______________________

SITE LOCATION: ______________________

PID #: ______________________

TEST PIT #: ______________ TECHNICIAN: ______________________

DATE: ______________ WEATHER/TEMPERATURE: ______________________

FIELD PERMEABILITY TEST #:

D – reservoir diameter (cm)		Soil Texture	
d – well hole diameter (cm)		Soil Structure	
H – height of water in well (cm)		α* (cm-1)	
Depth below ground surface (cm)		C – Factor	

TIME (min)	(1) CHANGE IN TIME (min)	RESERVOIR WATER LEVEL (WL) (cm)	(2) CHANGE IN WL (cm)	(2) ÷ (1) RATE OF FALL (R) (cm/min)

Quasi Steady-State Rate of Fall (R) = ______________ cm/min

APPENDIX B

Procedure to Verify Integrity of Permeameter Seals

Warranty Information

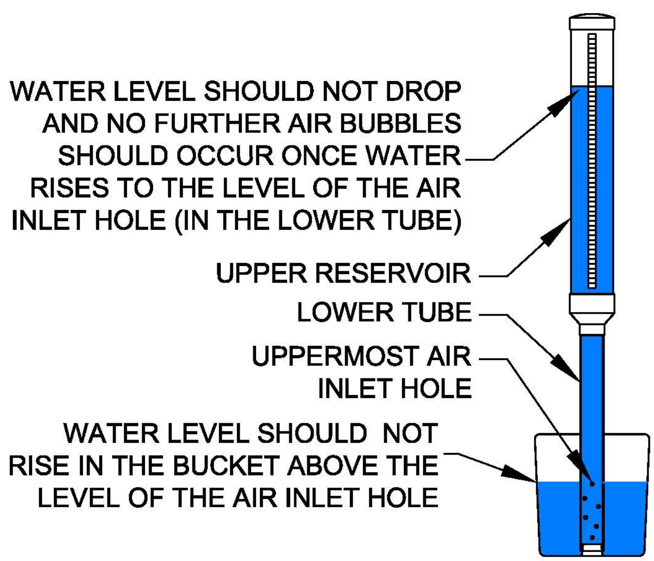
DYNAMIC MONITORS.COM

1-16 Myrtle Street, Stratford Business Park
Stratford, PE, Canada, C1B 2W2
Toll Free 1-888-747-7645 (SOIL)

ETC PASK PERMEAMETER – PROCEDURE TO VERIFY INTEGRITY OF PERMEAMETER SEALS

All ETC Pask Permeameters are tested at our facility to verify that they are water tight, before shipping to the customer. Dropping or rough handling of the permeameter could result in a crack or seal leakage. This could cause erroneous test results. Therefore, it is important that your Permeameter be checked immediately upon receipt ,and thereafter on a periodic basis to ensure it is water tight. The procedure recommended by ETC / Dynamic Monitors is provided below.

1) Pre-fill a minimum 150mm (6") deep bucket with water to a depth of at least 150mm (6"). Place the small bucket inside a larger deeper bucket in case water overflows or permeameter leaks.
2) Fill the permeameter with water. Attach cap to end of lower tube.
3) Turn the permeameter right side up into the small bucket (ie. same orientation as when conducting a test in the field).
4) Stabilize the permeameter so it will not fall over.
5) Water should rise to the level of the uppermost (air inlet) hole in the permeameter and stop.
6) Note the starting water level on the clear scale. Check the permeameter again after a minimum of 15 minutes. Note if the water level on the scale has dropped (it should not).
7) If the water level has dropped, or if there is any on-going air bubbling, it means that the permeameter is leaking. This will result in erroneous Kfs values.
8) If the permeameter is leaking, stop using it immediately. Contact Dynamic Monitors to see if it would be covered under warranty, or if it can be repaired.



1-16 Myrtle Street, Stratford Business Park
Stratford, PE, Canada, C1B 2W2
Toll Free 1-888-747-7645 (SOIL)

Product Registration & Warranty

Register your product with us so that we may keep you informed with any updates pertaining to scientific developments, formulas or the quick field calculation tables used with our permeameters, or of any significant developments related to determining permeability and hydraulic conductivity using constant or falling head permeameters.

Dynamic Monitors will extend warranty coverage to two (2) years when you register your product within thirty (30) days of purchase. If you do not register your product, the one (1) year Base Limited Warranty will apply.

REGISTER YOUR PERMEAMETER ON-LINE TODAY

To review detailed warranty terms and to be eligible for the 2 Year, extended Registered Limited Warranty, visit our web site (**DynamicMonitors.com**) under the "**RESOURCES**" tab or by visiting this link:

https://dynamicmonitors.com/permeameter-warranty-product-registration/