An Automated Dual-Head Infiltrometer for Measuring Field Saturated Hydraulic Conductivity

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Introduction

We developed an automated infiltrometer capable of producing variable hydraulic head conditions without actually varying the water depth and without requiring user intervention. This will enable a user to run multiple infiltrometers at one time getting a better quantification of spatial variability. We used the Reynolds and Elrick (1990) and Nimmo et al. (2009) methods of analysis for steady flow from ponded infiltration, in a single ring, which enables us to accurately calculate the saturated hydraulic conductivity (K_{fs}) of soils in the field. This can replace the method that requires constant monitoring and user intervention to change water levels, and can take hours for the user to complete a single measurement.

Dual-head Infiltrometer Equations

Nimmo et al. (2009) compute the field saturated conductivity from

$$K_{fs} = i/F \qquad (1)$$

where *i* (cm/s) is the steady (final) infiltration rate (volume divided by area) and *F* is a function that corrects for sorptivity and geometrical effects. *F* is computed from

$$F = 1 + (\lambda + D)/\Delta \qquad (2)$$

where *D* is the ponding depth (cm), *d* is the insertion depth of the infiltrometer (cm), *b* is the infiltrometer radius (cm), and λ (cm) is the reciprocal of the Gardner α which is a characteristic of the soil and its initial water content. Equations 1 and 2 are originally from Reynolds and Elrick (1990). Δ in eq. 2 is 0.993*d* + 0.578*b*.

If we know infiltration rate at two ponding depths we can eliminate λ using equations 1 and 2, written for the two depths, to get

$$K_{fs} = \Delta(i_2 - i_1)/(D_2 - D_1) \qquad (3)$$

Δ is a constant for a particular size infiltrometer. For our infiltrometers *d* = 5 cm and *b* = 5, 7.5 or 10 cm, so Δ = 7.85, 9.3 or 10.7 cm. The hydraulic conductivity is therefore just the infiltration rate difference divided by the ponding depth difference multiplied by delta. The infiltration rate is the flow (cm^3/s) divided by the infiltrometer area. The areas for our infiltrometers is 79, 177 or 314 cm^2.

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References

Nimmo, J. R., K. M. Schmidt, K. S. Perkins and J. D. Stock. 2009. Rapid measurement of field-saturated hydraulic conductivity for areal characterization. Vadose Zone J. 8:142-149.

Reynolds, W. D. and D. E. Elrick. 1990. Ponded infiltration from a single ring. I. Analysis of stead flow. Soil Sci. Soc. Am J. 54:1233-1241

Design & Performance

- •Peristaltic pump for water supply and volume measurement
- •Capacitance probe for depth control
- •Air pressure control to set and change head
- •Hall effect sensor to measure water pump revolutions
- •3 heavy steel rings for different flow rates
- •Quick connect sealing lid
- •CR3000 Data logger for measurement and control

Pressure
Range: -20 to 30 cm H_2O

Flow Rates
20 cm ring
Low flow rates
2.5×10^{-5} to 9.2×10^{-4} cm/sec

15 cm ring
Medium low rates
1.48×10^{-3} to 4.32×10^{-3} cm/sec

10 cm ring
High flow rates
2.1×10^{-3} to 9.6×10^{-3} cm/sec

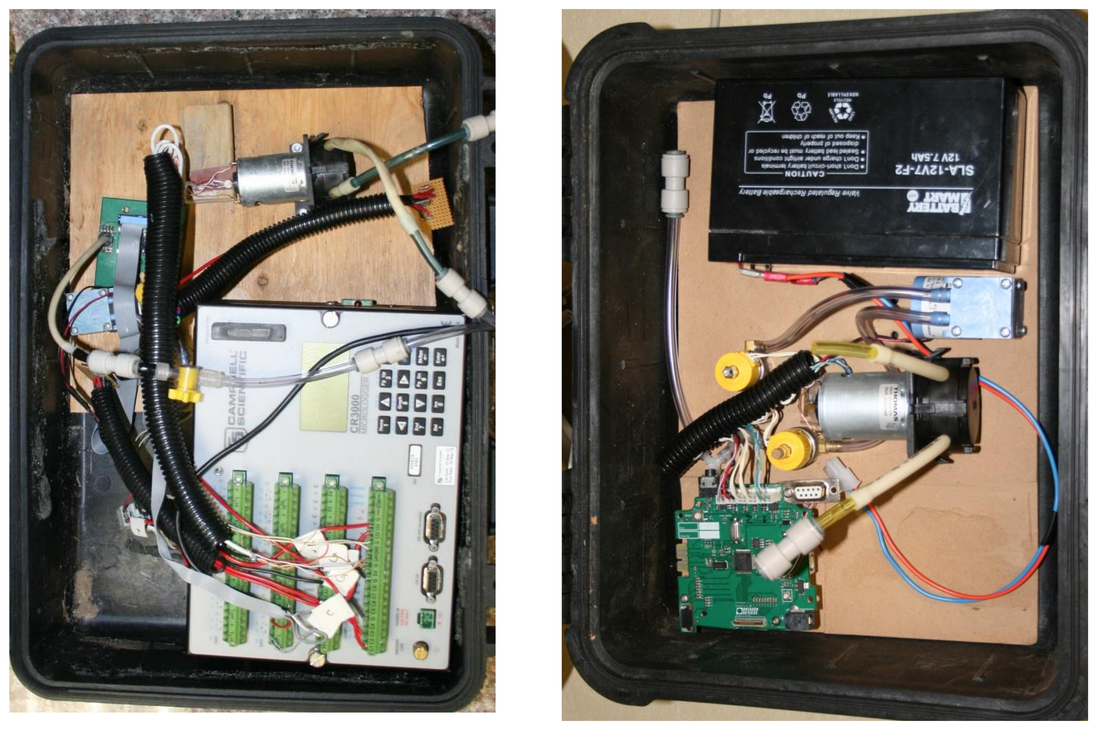

Figure 1. Internal layout of infiltrometer. On left is original prototype with data logger. On right is second edition with purpose built board.

Figure 2. Testing infiltration on the soccer field.

Field results

Table 1. Table of infiltration rates for 12 different locations.

Location	K_{fs} ($cm\ h^{-1}$)	Ring Size (cm)
Clay	0.09	20
Clay	0.61	20
Silt Loam 1	2.20	20
Silt Loam 2	3.32	20
Silt Loam Under Grass	5.33	15
Untilled-Structured Silt Loam	15.55	15
Soccer Field 1	18.47	15
Soccer Field 2	7.78	10
Vantage Sand 1	8.14	10
Vantage Sand 2	9.47	10
Soccer Field 3	21.82	10
Soccer Field 4	34.45	10

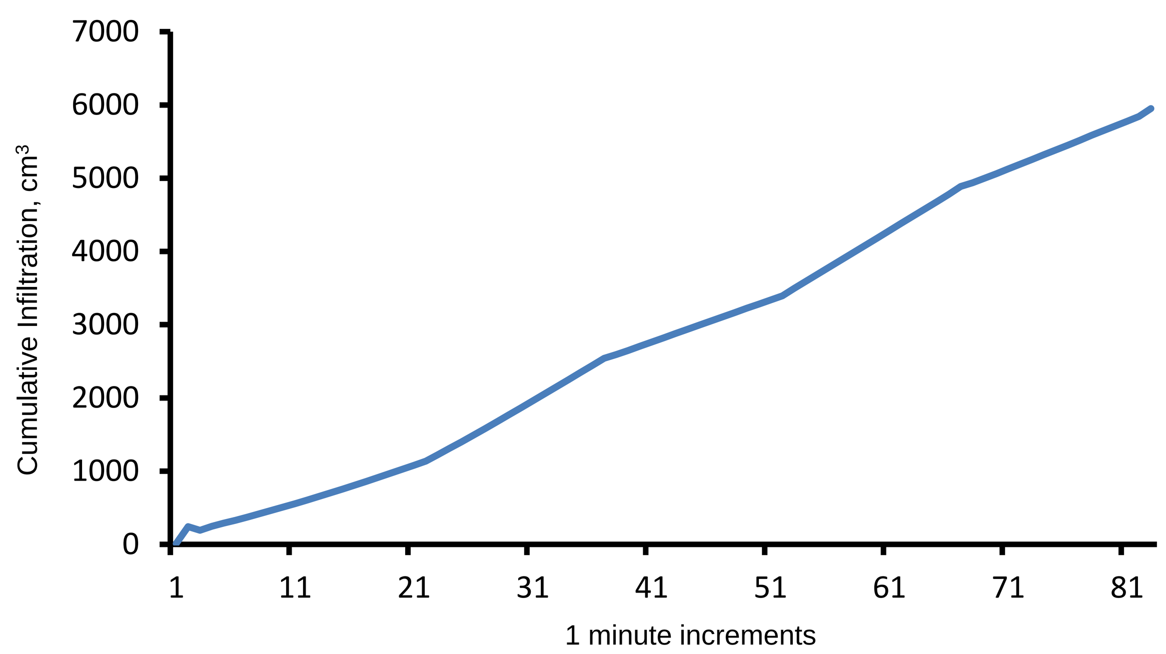

Figure 3. Cumulative water quantity over time. The slope changes are when the pressure head switches.

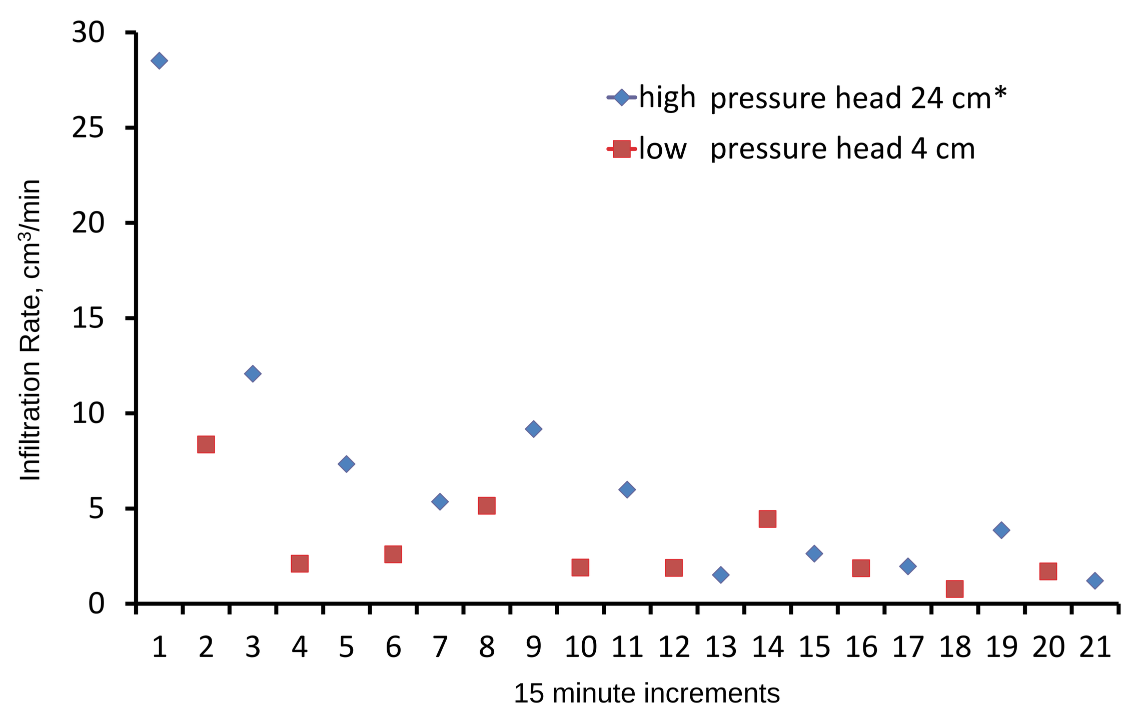

Figure 4. 10 inch ring on Clay, Shows variability at extreme lower edge of measurable range. * simulated pressure head

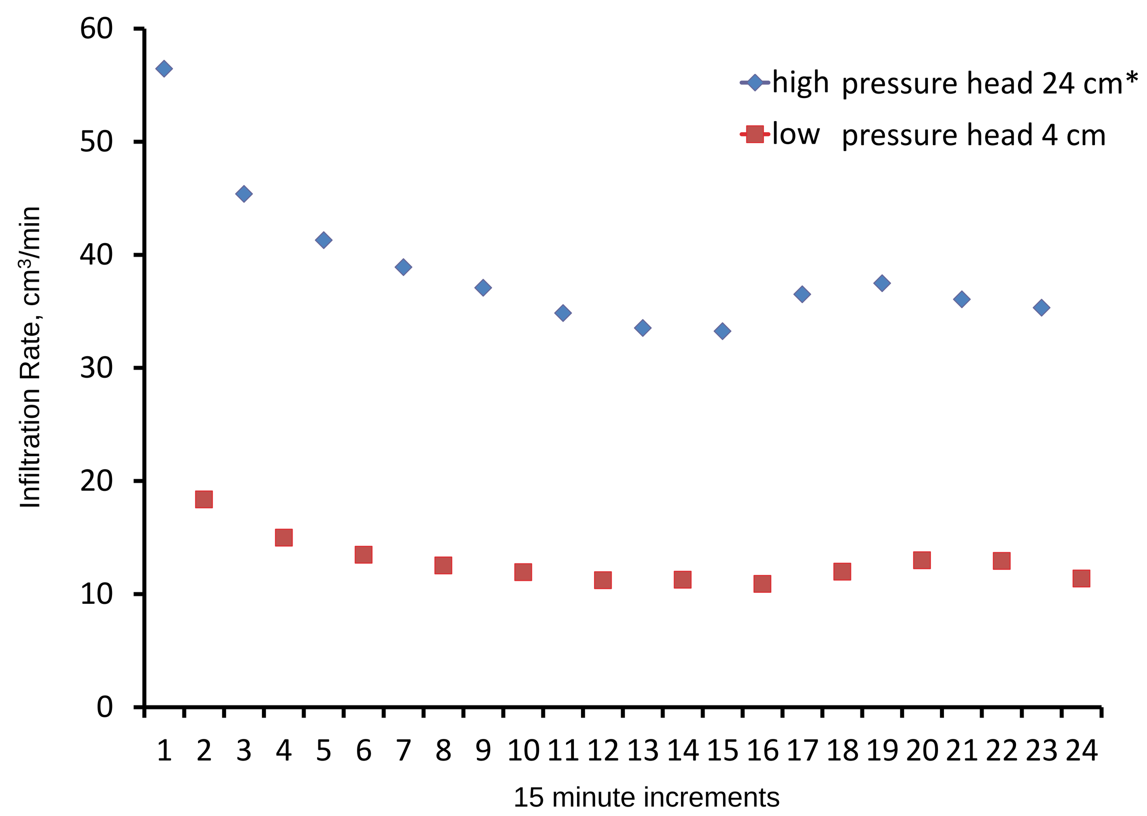

Figure 5. 4 inch ring on Soccer Field, shows a little variability over long time span.