Review of *Examining the effect of pore size distribution and shape on flow through unsaturated peat using 3-D computed tomography* by F. Rezanezhad, W. L. Quinton, J. S. Price, D. Elrick, T. R. Elliot, and R. J. Heck published online in *Hydrology and Earth System Sciences Discussions*.

Overview.

This paper is true to its title and reports on the use of x-ray CT as a technique to derive pore metrics that can be used to describe the unsaturated hydraulic conductivity (*K*) of a peat soil. The authors show how a pore shape coefficient can be obtained from x-ray CT images and how its use in the equations of Hazen and Kozeny-Carman provides an accurate description of the relationship between unsaturated hydraulic conductivity and pore-water pressure (*p*). The paper deserves to be published because it reveals the factors that affect *K* in one type of peat and also shows the potential of x-ray CT for investigating water-flow processes in peat. However, I recommend that the paper is revised and that the authors comment on four issues. First, they use a single peat sample. How representative is this sample of a wider class of peat soils? It worries me that many people consider 'peat' as a single soil type when in fact it describes a range of soil types almost as diverse as mineral soils. Secondly, the authors measure horizontal *K* when I would expect most water movement in the unsaturated zone to be vertical. In many *Sphagnum* peats there is a zone of collapse about 1-2 dm below the soil surface in which the orientation of *Sphagnum* stems and branches changes from vertical to horizontal. It would be useful to know more about the sample of peat studied and how stem orientation may have affected the pore-shape metric – *c* – and what implications such orientation may have for water movement in poorly-decomposed *Sphagnum* peat. Thirdly, it would be useful to know whether the authors think it is practicable and desirable to model unsaturated water flow in poorly-decomposed *Sphagnum* using a Darcy-type equation. Previous studies (see detailed comments) suggest that flow of rain-water through poorly-decomposed near-surface peat is rapid, and, for many practical purposes, can be considered to arrive immediately at the water table. For situations where capillary rise of water from the water table is exceeded by evaporative water loss from *Sphagnum* capitula – so that capillarity theory cannot be used to describe the distribution of water content above the water table – a simple storage model may be a more satisfactory description of unsaturated water dynamics than a variant of Darcy's law. Finally, although I agree that it is interesting to discover the factors that control water flow in unsaturated peats, I wonder whether the authors are proposing their approach as a practical alternative to deriving *K*(*p*) empirically; i.e., as an alternative to by measuring *K*(*p*) directly? If so, I think it would be good to see an explanation of why they think their approach is better.

Detailed comments (more substantive comments are given in bold).

Page 3836, line 3, "peat structure which affects the air-filled porosity, pore size distribution and shape". Surely, this should be the other way round; 'structure' is a term that describes porosity, pore shape, size and connectivity, bulk density and other physical properties of a soil.

Page 3836, lines 9-10, "that pore distribution is dominated by a single large pore-space". I don't follow. Do the authors mean the flow of water through the soil is dominated by the single, large pore? What do they mean by 'pore distribution'? Are they referring to a single metric or measure of the pore size distribution?

Page 3837, line 10, “The reduction in the total porosity with depth is minimal”. I disagree; typically, total peat porosity declines from >0.95 in new peat litter (proto-peat) to ~0.8 in well-decomposed, compressed peat. Such a change is not negligible.

Page 3837, lines13-15. Okay, but studies have shown that hydraulic conductivity (*K*) does not necessarily show a monotonic decline with depth. For example, Beckwith *et al*. (2003) (which is cited by the authors) showed that *K* varies dramatically with depth, and concluded that there was not a simple relationship between *K* and depth.

Page 3839. I think the study of Kettridge and Binley (2008) should be cited somewhere in this part of the introduction because they went beyond thin sections and were able to construct metrics of *Sphagnum* stem and branch size and orientation (which in turn affect pore size and orientation) in a peat apparently similar to that studied by the authors.

Reference:

Kettridge, N., and Binley, A. 2008. X-ray computed tomography of peat soils: measuring gas content and peat structure. *Hydrological Processes*, 22, 4827-4837, doi: 10.1002/hyp.7097.

Page 3840. It would be helpful to know more about the soil. Of what species of *Sphagnum* was it composed? What other plant species were present. What did its decomposition profile look like? If the authors have any photographs of the block, then it would be useful to include one in a revised paper so readers are able to compare it with the profile of other peats. It would also be useful if the authors could justify briefly why they looked at this particular peat type.

Page 3841. Why did the authors look at horizontal hydraulic conductivity? I would have thought that most unsaturated water flow in bog or *Sphagnum* peats is vertical or approximately vertical. We know the latter from field and laboratory observations that show that rainfall is relatively rapidly transmitted through the unsaturated zone, which leads to water-table rise, with subsequent water-table lowering occurring in response to horizontal seepage below the water table and in response to evaporation and transpiration (e.g. Hayward and Clymo, 1982; Kettridge and Baird, 2007 and 2008). It seems somewhat odd (to me at least) that vertical *K* was not looked at.

References:

Hayward, P. and Clymo, R. 1982. Profiles of water content and pore size in *Sphagnum* and peat, and their relation to peat bog ecology. *Proceedings of the Royal Society of London*, Series B, 215, 299–325.

Kettridge, N., and Baird, A.J. 2007. In situ measurements of the thermal properties of a northern peatland: Implications for peatland temperature models. *Journal of Geophysical Research*, 112, F02019, doi:10.1029/2006JF000655.

Kettridge, N., and Baird, A.J. 2008. Modelling soil temperatures in northern peatlands. *European Journal of Soil Science* 59, 327-338, doi: 10.1111/j.1365-2389.2007.010000.x.

Page 3841, line 21. *Q* is defined by its units (mL s^{-1}), but *A*, *h*, and *L* are defined by their dimensions. Only one or the other should be used.

Page 3842, line 20. There is a superfluous space and comma on this line. Are the air bubbles referred to those trapped in the quasi-saturated peat below the water table?

Page 3843, line 8. Was any attempt made to distinguish between the solid (peat) phase and the liquid phase?

Page 3843, line 27, “before analysing the pore distribution analysis”. I recommend re-phasing; ‘analysing an analysis’ is an awkward expression.

Page 3844, line 19. This should read “point**s** that separate” or “point that separate**s**”.

Page 3844, line 23. Kettridge and Binley (2008) used lead (II) to help distinguish between the solid and liquid phases. Have the authors tried anything similar? Clearly, it would be useful to be able to image the whole pore network and to analyse that part of it in which water resides during drying so see if the peat behaves according to classical capillarity theory.

Page 3845, line 19, "little variation among them [the peat subsamples] in terms of their physical and hydraulic properties" (my parenthess). I find this surprising, given that the total porosity of the middle was substantially lower than the upper and lower subsamples (0.863, compared with 0.955 and 0.933).

Page 3846, line 20. "R_p is the pore radius factor measured between 0.001 to 2.36 cm". I don't follow what the authors are trying to say here. What is meant by "measured between 0.001 to 2.36 cm"? Do they mean the pore radius factor *varies* between the two values?

Page 3847, lines 16-17. The wording here is unclear. On the one hand the authors seem to be suggesting that flow in the large pore is efficient, while on the other they seem to be saying that the large pore exerts more resistance to flow.

Page 3847, lines 18-19. "All other smaller pores are contributing to the obstruction of flow and their contribution to flow may be neglected when a very large pore is active." Would it be better to reword this as follows: "Although smaller pores may contribute to the obstruction of flow, their contribution to flow may be neglected when a very large pore is active."?

Page 3847, lines 22-23. This should read "**the** single large" (insert 'the').

Page 3848, line 3. The sentence starting on this line is ungrammatical and would benefit from rewording.

Page 3848, line 9. Why does "Pore" start with a capital letter?

Page 3848, line 18. Why simultaneous?

Page 3849, line 24. This should read "**the** Hazen" (insert 'the').

Page 3850, line 26. This should read "**a** standard" (insert 'a').

Page 3851, line 2. I recommend rewording as follows: "drops by a similar amount to the".

Page 3851, line 24. Sands are mineral soils. The statement here is perhaps too general. I doubt the equations used in this paper apply to some clay soils, especially those that swell and shrink, where flow is dominated by flow through planar macropores. In addition, I recommend rewording this line as follows "in peat soils **in** which" (insert 'in').

Page 3852, line 4. Delete "that".

Page 3852, line 22. Delete "developed".

Andy Baird
University of Leeds, UK
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