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Hydrology and Earth System Sciences Discussions

Interactive comment on "Temporal variation in depth to water table and hydrochemistry in three raised bogs and their laggs in coastal British Columbia, Canada" *by* S. A. Howie and H. J. van Meerveld

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We thank the reviewer for his/her review. We address each comment below.

General Comments:

1. Determination of depth to water table: The reviewer expresses the same concerns as Referee #1 regarding the determination of depth to water table with shallow piezometers. Based on the data presented in our response to Referee #1 (i. the small

differences in water level measured in a shallow piezometer and a well, ii. the small differences in water level measured in a shallow piezometer and a deeper piezometer, suggesting very small gradients in head, even in a lagg site, and iii. small differences between the water level on the surface and water level in the shallow piezometers during ponding conditions), we expect that the error due to using shallow piezometers to determine depth to water table is small (e.g. <1-2 cm) and of almost similar magnitude as the error in determining the surface level. Furthermore, we did not observe significant clay layers in the peat during installation of the piezometers (ash content in the profiles occupied by the piezometers was <15% for the "bog", "trans1", "trans2", and "lagg" sites), and rainfall intensities are generally very low in this coastal area so that the temporal variability in the heads measured in the piezometers can be expected to be highly correlated to the temporal variability in the location of the water table (as shown by the similar water levels in a well and piezometer – see ii). We agree that we need to add a description of these uncertainties to inform the readers about the reliability (and appropriateness) of these measurements and point out that we are not studying water level responses during events but rather the broad seasonal patterns in depth to water table and how this varies across the bog expanse – bog margin transition. Furthermore, we will reword the text to explain that we did not measure depth to water table in the piezometers but rather determined the depth to water table from these measurements. Adding a discussion about the potential error due to the use of shallow piezometers instead of wells still gives the readers information about the seasonal water level fluctuations across the bog expanse – bog margin transition, while at the same time being transparent and clear about the methodology.

As Referee #2 suggested, we can add a description of when the piezometers were acting as wells (i.e. when the water table was at or below the level of the screening), and when the piezometers were acting as piezometers (i.e. when the water table was above the screening). In general, the piezometers acted as wells in late summer (August-September) and as piezometers from autumn to early summer (October-June). This additional information will also provide more clarity about our methodology, while adding more information about the other measurements (i-iii as given in the response to Referee #1) would provide more confidence in the information presented.

2. Introduction: As suggested by both referees, we will revise the Introduction to make it clearer that the focus of the paper is on the lagg, and more specifically the reliability of a single survey to determine gradients in depth to water table and pore water chemistry across the bog expanse – bog margin transition.

Specific Comments:

14071:22-14072:7: The reviewer suggests moving the first section of our Study Sites description to the beginning of the Introduction. We placed this text in the Study Sites section because it is specifically related to the study locations, whereas the Introduction discusses the topic in a more general sense. However, we can reorganize this text if the Editor shares the opinion of the reviewer.

14071:7-12: This text can be moved to the Introduction and be supported by references, as suggested by the reviewer. However, the reason this text was placed here, was to provide the rationale for the objectives of this study. The second objective can be explained in the Introduction. We can add a third objective related to the "watering-up" effect to this section as well.

14072: We can add a reference to Table 1 here; there is also a reference to Table 1 at 14074:26.

14073:15-25: Referee #1 also suggested putting this information in a table; we plan to replace this paragraph with a table.

14074:1-5: Lagg1 and Lagg2 are the two lagg study sites on the Sherwood and DNR transects in Burns Bog. We will add a definition of these two names in the text and the caption of Table 2.

14074:18: See "Determination of Depth to Water table" above.

14076:18: We will change the word "maximum" to "average of the annual low point of the water table", and replace the 30-40 cm range with the average value for the 6 year period shown in the figure (34 cm).

14077:4-15: In Figure 2 we show that the increase in water level was i) larger for the logged site than for any of the unlogged sites on the SW transect and ii) that the difference was larger for the logged "lagg" site (on the SW transect) than for any of the unlogged "lagg" sites (i.e. on the other transects). We describe this on Page 14077, Lines 1-7, and Page 14086, Lines 11-16. We can focus even more on the 2011 data and reword the comparison between 2010 and 2011 to make this clearer and avoid any unintended confusion.

14077:11: We will add the following text to point out that salal growth is only one possible reason why the water level was lower in the logged site in 2012: "Mean July and August air temperature at Vancouver International Airport was the same in 2011 and 2012 (18 degrees C), but there was less precipitation during this period in 2012 (31 mm) than in 2011 (57 mm), which can, in part, also account for the lower water level in 2012."

14077:20-14078:5: It was not our intent to suggest that a single hydrochemical sample is "enough to show a whole season hydrochemistry". We intended to show i) that the measured pH and EC varied little over the 1.5-year sampling period, and that a single measurement in June or July is thus reasonably representative of the average, and ii) that a single survey or measurement campaign will thus give a reasonable representation of the gradients across the bog expanse – bog margin transition. The reviewer is correct that we do not have a long-term average with which to compare our data from the 1.5-year study and agree that this needs to be worded more clearly to avoid any unintended confusion. Thus, we will add a discussion about this in the text and make it clear that our intent is to point out that based on the data that we collected, pH and EC appear to be relatively stable over time and that gradients across the bog expanse – bog margin transition determined from one survey are relatively stable as well, but that longer time series, and especially more frequent measurements during events are needed to validate this result and to determine if there are larger changes in EC and pH during events. We already point out the lack of detailed measurements during events in the Introduction (14070:6-10) but will stress the need for high resolution measurements, especially during rainfall events, again in the discussion.

14080:19: Our intent was to show that there are differences in pH and EC across the bog expanse – bog margin transition. We agree with the reviewer that a comparison is required to determine which of the locations on the transect was statistically different from the others. We can add this analysis to the paper and will include the results in a table. We calculated Tukey's HSD for each transect, and found that for each transect the locations that were significantly different from the others on the transect was different. For example, on the Cranwest transect, pH at the "lagg" site was significantly different from the "bog" site, and pH at the "mineral" site was significantly different from all other locations on the transect. For the Blaney UP transect, on the other hand, pH was significantly different from the other locations on the transect for most of the sites.

14081:17-19: We are aware that the water level (and heads) in bogs can fluctuate rapidly in response to precipitation, and that a single measurement is not likely to capture the maximum or minimum water level in a given year. For example, Figure 1 below shows the water level in a shallow piezometer in Burns Bog, Delta, BC, which shows increases in water level in response to rainfall events, with a gradual decline afterwards, and also some small daily fluctuations. Our intent was to explain that the hydroperiod in coastal BC follows a similar pattern each year, and that although water levels fluctuate in response to rainfall events, these fluctuations average out to a certain average high point of the water table (i.e. a high base level near the bog surface with increases due to rainfall on top of this high base level) during winter and early spring and an average low point of the water table (e.g. ∼40 cm below the surface) during late summer. We will make this explanation clearer and remove the unintentional suggestion that the maximum (or minimum) level of the water table can be reliably measured on any given

day during the winter (or late summer).

Bogs are not always studied for research purposes, but may simply be studied to gain a general idea of the fluctuation in the water table, in order to determine whether the water table fluctuates within the general range for undisturbed bogs in the region, or whether the water table is lower so that Sphagnum regeneration may be hindered and the bog may require restoration. We will make it even clearer that we are discussing these general trends and differences here and not specific responses to rainfall events.

14082:7-8: We will reword this section and add references to make this section clearer. The objective of our study was to determine whether pH and EC (and other hydrochemical parameters) change significantly over time or whether a one-time survey can reasonably represent the spatial gradients in hydrochemical characteristics across the bog expanse – bog margin transition. We found that they did not change significantly over time for a given site, regardless of the depth of the water level in the piezometer below the bog surface or the depth of the piezometer.

The purpose of this statement was to explain that pore-water chemistry is buffered against changes in precipitation chemistry, and that the buffering effect likely becomes greater with depth because new rainfall moves slowly through the peat and most water movement is (laterally) through the poorly decomposed, porous upper peat. Furthermore, ion concentrations may be higher during periods of intense evaporation (concentration effect), and lower during periods of high rainfall (dilution effect). We found a statistically significant linear correlation between depth to water table and pH ($p=0.031$), and a statistically significant Spearman rank correlation between depth to water table and EC ($p=0.010$) (see Figure 2 below). However, these results do not indicate that pore water was more diluted when the water level was close to the surface (wet periods) or that ions were concentrated when the water level was deeper (dry periods), indicating buffering of pore water chemistry.

pH and EC can change with depth in peat (Vitt et al. 1995) due to changes in peat characteristics (e.g. level of decomposition, bulk density) with depth (Egglesmann et al. 1993). These changes in pH and EC (and other hydrochemical variables) with depth reflect the peat structure in the bog. We did not find a relation between the average pH or EC and the depth of the screening of the piezometers for the relatively narrow range in the depth of the piezometers in this study (see Figure 3).

The pH and EC were always measured at the top of the water column in the piezometer to avoid any influence due to stratification inside the piezometer. This was just a precaution; we did not observe any stratification during sampling.

14082:17-18: Our intent was to point out the few "spikes" in EC to give the reader more information about the representativeness of a single sample or the variability in EC between repeated measurements. As pointed in the previous comment, buffering of pore water chemistry to changes in precipitation chemistry takes place (due to the high cation exchange capacity of the peat) and this buffering may be larger at deeper depths, but these spikes in EC occurred for piezometers at various depths (0.58-1.10 m below the surface; average: 0.89 m), not only the shallowest piezometers.

We do not know the cause of these spikes (there could indeed be less buffering at these locations at these times) but we point them out to show that there is temporal variability in EC. We will stress this more this clearly in the text.

14084:14-30: We agree and will add the information about DOC to the Introduction and Results, as suggested by the reviewer.

References

Vitt, D.H., Bayley, S.E. and Jin, T.: Seasonal variation in water chemistry over a bog-rich fen gradient in Continental Western Canada, Canadian Journal of Fisheries and Aquatic Sciences, 52, 587-606, 1995.

Egglesmann, R., Heathwaite, A.L., Grosse-Brauckmann, G., Kuster, E., Naucke, W., Schuch, M., and Schweickle, V.: Physical processes and properties of mires, in: Heath-

waite, A.L. and Gottlich, Kh. (eds.), Mires: Process, Exploitation and Conservation, John Wiley & Sons Ltd., Chichester, 171-262, 1993.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 14065, 2012.

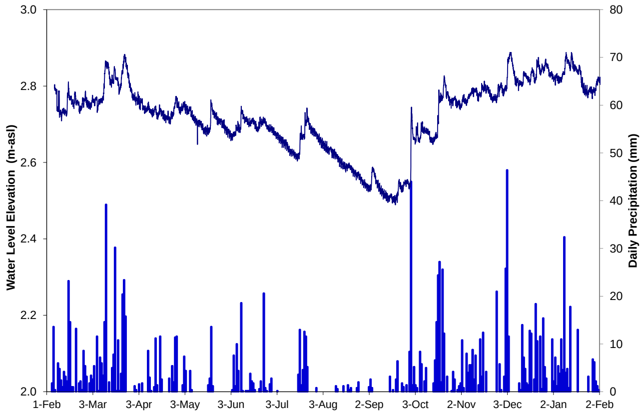

Fig. 1. Figure 1: Hourly water level elevation in a shallow piezometer in Burns Bog, Delta, BC, and daily precipitation at Vancouver International Airport, for February 2007 through February 2008.

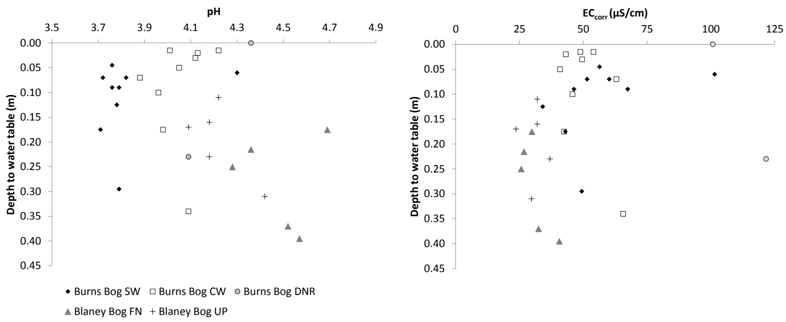

Fig. 2. Relation between depth to water table and 1) pH and 2) pH-corrected electrical conductivity for "bog" sites on the Burns Bog and Blaney Bog transects in our study.

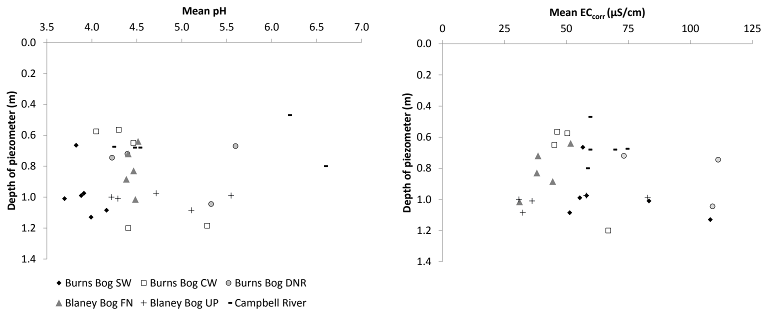

Fig. 3. Relation between depth of piezometer and 1) mean pH and 2) mean pH-corrected electrical conductivity for all piezometers in our study.