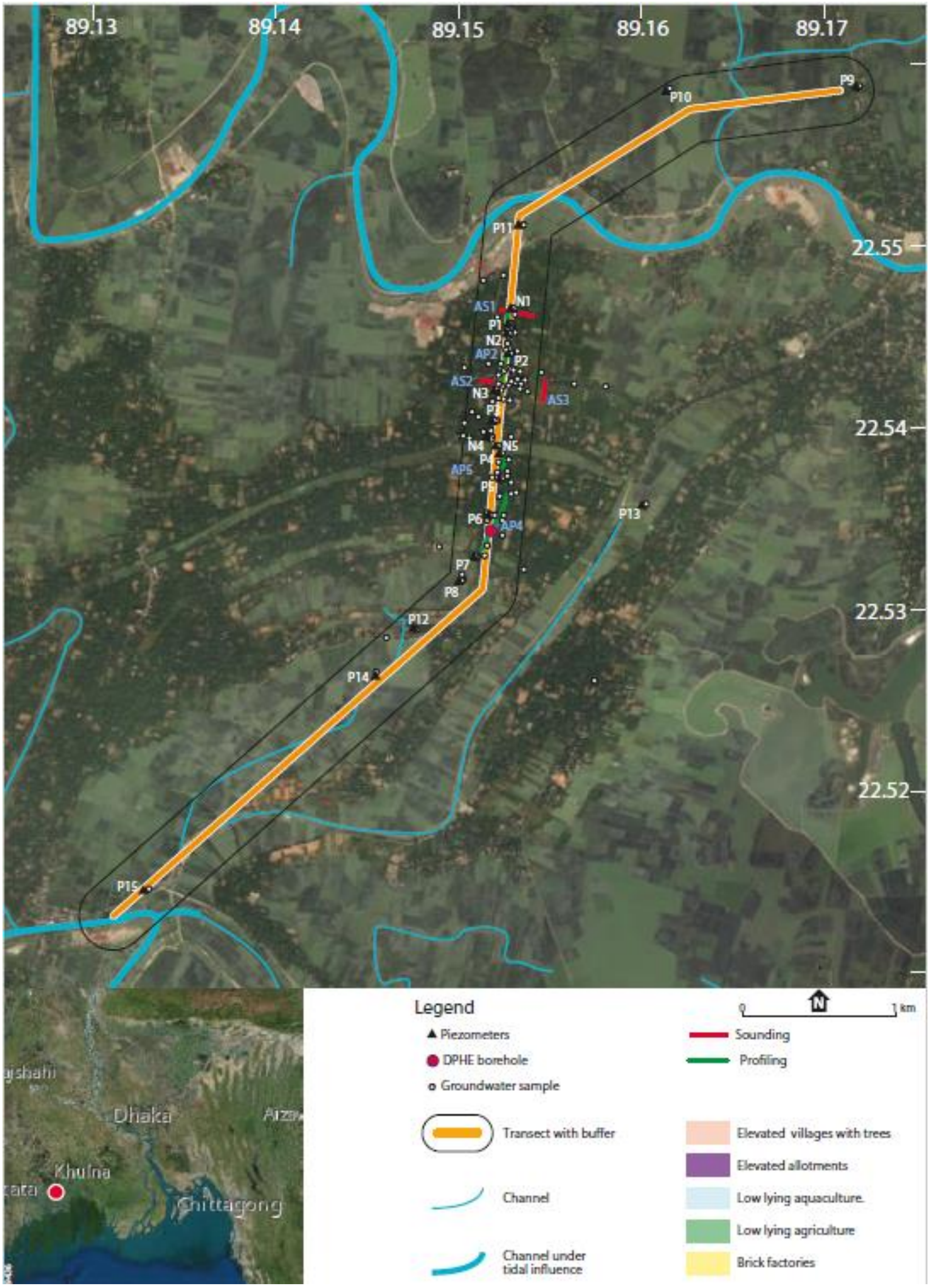
Author’s response to anonymous referee #1

1. Reviewer’s comment: This study explores groundwater salinity variations in a village in southwestern Bangladesh using (1) geological evolution, (2) groundwater and lithological sampling, and (3) modeling. The paper is well written and logically describes the aim, methods, and findings of the groundwater investigation.
Author response: We thank the referee for his time to review our paper.

2. Reviewer’s comment: Figure 1 seems insufficient for the reader to fully understand the field site. An additional satellite image would give the reader a better sense of the region. Perhaps consider a two-paneled figure with a satellite image adjacent to the site diagram. An additional figure in an appendix would also suffice.
Author response: We agree that we can be more clear.
Changes in manuscript: We will add a figure with satellite imagery, either in the appendix or as a two-paneled figure. The following figure with satellite imagery will be added



3. Reviewer's comment: To connect back to the first paragraph of your introduction, I would be interested in how you could relate your findings back to drinking water availability. Is there enough freshwater to sustain the villages with drinking water? Is it likely that the freshwater recharge in high elevation regions will recharge at a pace similar to the salinization from the nearby low-lying regions and aquaculture? See line 520.

Author response: This is indeed an important question. Unfortunately, the exact fluxes of water are hard to estimate. It is difficult to assess the exact amount of water that is being extracted and used, as the fresh water is used without regulation for both drinking/household water and irrigation water. Additionally, it is difficult to determine or estimate the recharge of fresh water, because of the (varying) clay cover thickness and the uncertain amount of recharge from fresh water ponds (article line 486-494).

We state that salinization from the aquaculture ponds could be a threat to the fresh groundwater, following the observation of salinization in the groundwater in the southern part of the village (Figure 7). The exact impact of salinization of low-lying regions on the fresh groundwater requires temporal measurements and modelling of groundwater flow.

For these reasons, we didn't aim to make an estimate of the fluxes and the sustainability of the fresh groundwater resource under present-day circumstances, which we acknowledge as a shortcoming in line 550. We see this as beyond the scope of this work, and as a topic for further research.

Changes in manuscript: No change

4. Reviewer's comment: One of the main conclusions is that elevation is correlated with groundwater salinity, where higher elevations are fresher than lower areas. This appears to be a poldered region surrounded by tidal creeks (as noted by the embankments in Fig. 2). The polder regions in SW Bangladesh are highly altered. The inhabitants have cleared forests, built embankments, compacted the landscaped by limiting flooding, dug ponds, and raised areas around their villages. There is a massive amount of sediment movement at the surface. Does this study area have _2 m natural variation in topography (partial answer in 4.1.3 b)? Or is the difference in elevation observed across the transect a recent development due to anthropogenic activity? If so, does that change how you would interpret the correlation between groundwater salinity and elevation? Could the salinity variations be more closely related to clay cap thickness?

Author response: We found a natural variation in topography of approximately 1.5m, based on our elevation measurements (par. 2.2.2).

It is true that a large anthropogenic influence is typical for the topography in the polders in Bangladesh. In our specific study area, we think that the main elevation differences are natural, for multiple reasons:

- The high area is very large, with a width of approximately 2 km (Figure 1), which is much larger than the anthropogenically created narrow high ridges next to creeks or next to roads that are present throughout most of the polders.
- The high area has a fluvial soil type, which suggests natural formation (FAO, 1959).
- This high lying area meanders naturally through the landscape, which also suggests a fluvial, natural origin.

"*Could the salinity variations be more closely related to clay cap thickness?*" When looking at Figure 3, we observe that the salinity of the groundwater is not only related to the clay cap thickness. In the low-lying areas directly surrounding the high-lying village (near N1, near P8 and near P14), the clay cap is similarly thin as below the high-area, but the groundwater salinity is saline instead of fresh. This indicates that clay thickness alone can't explain the salinity differences.

Changes in manuscript: No change

5. Reviewer's comment: What are the coordinates for the study area? This should be included in Fig. 1 or line 76.

Changes in manuscript: We added coordinates to Figure 1.

6. Reviewer's comment: I'm a bit unsure how the "groundwater observation well" and "groundwater sample" data are different. Why include P16 and P17?

Author response: 'Groundwater observation well' indicates a groundwater sample taken from a newly placed well (with a filter of 5 ft). A groundwater sample refers to any sample we took from the groundwater, including samples from household tubewells.

The installation of P16 and P17 had two goals:

1. They were used to better assess the lithological situation between P11 and P10.
2. They are used to determine whether density driven flow could lead to salinization of the water below the thick clay layer (see line 453).

Changes in manuscript: Clarified the type of tubewell: Added '*household'* in line 124 and in Table 1.

Clarified the use of P16 and P17: added '*to get more detailed lithological information between P11 and P10*' in line 100.

7. Reviewer's comment: Some of your groundwater tubes appear to be installed in the clay. In similar field environments, I have had difficulty extracting groundwater samples from clay layers, especially using hand-flapper drilling methods. It always important to acknowledge the potential inaccuracies associated with this type of field environment. This type of tube installation can be a major source of error when dating or looking at cation exchange. Are you confident that you were able to evacuate the installation water, pump the tube, and extract groundwater despite the low permeability of the clay layer? It may be worth noting the potential limitations of the hand-flapper installation method.

Author response: We are indeed not very clear in this regard. We didn't extract water from the clay by groundwater tubes, but we used the open auger boring method (De Goffau et al., 2012, see pictures below). We drilled a hole with a hand auger, without any drilling fluid. Then we waited for the hole to fill with water, which we sampled by inserting a sample bottle into the hole with a stick, which we pulled back out using a rope that was attached to the bottle. We called these samples retrieved from 'Hand-auger borings' in Table 1, but we didn't specifically described the field procedure of these samples.



Changes in the manuscript: Added a sentence in line 126 '*To sample porewater from the clay, we used the open auger boring method (De Goffau et al., 2012). We drilled a hole with a hand auger, without any drilling fluid. Then we waited for the hole to fill with water, which we sampled by inserting a sample bottle into the hole with a stick, which we pulled back out using a rope that was attached to the bottle.*' Changed the name of these samples from '*hand-auger borings*' to '*open auger borings*'

8. Reviewer's comment: The variation in the clay cap thickness is substantial. Figure 3 shows the thickness varying from 5 to 35 m. The thickness of the cap has to play a major role in present-day surface water influence on groundwater salinity. Yet Figure 7 shows both freshening and salinization under the thickest region of the clay cap (near P9, P10, and P15). Can you better explain how the freshening and salinization stages can differentiate between current day processes (e.g. salinization due to aquaculture) and depositional processes (e.g. salinization due to evaporation of pore water during deposition of sediments 10 kyr BP)? Can you discuss any uncertainties associated with this methodology (without the use of dating), especially in an area with highly variable connate water? Most of these questions arose from the section 3.8.2. You do a nice job of answering some of these questions in your phased subsurface evolution in section 4.

Author response: The stage of freshening or salinization alone cannot be used to differentiate between salinization by aquaculture or salinization by depositional processes. The salinization stages were used to determine the direction of salinization (see section 3.8.2).

The difference between present-day and depositional processes are, instead, postulated after combining the field results with the geological history described in literature, which we describe in section 4.1. In section 4.2, we acknowledge that our postulated evolution of the groundwater salinity is uncertain, and that it should be seen as a conceptual model.

Changes in the manuscript: Added a sentence in line 550: '*Without age dating, we can't determine the exact moment of salinization or freshening that has occurred.*'

9. Referee comment: Do you see any seasonal changes in groundwater salinity associated with exchange with the tidal channels? If you see signatures of salinization and freshwater recharge in the thinned cap areas, how do you expect the groundwater signatures to compare near the tidal channels?

Author response: We didn't look in detail at interaction of the aquifer with the tidal river, nor did we study temporal variety in salinity in the groundwater in great detail. As a consequence, we have no evidence for seasonal groundwater salinity near the tidal channel.

Without detailed and temporal measurements of water levels/heads in both the river and the aquifer, it is difficult to say what we expect near the tidal rivers. There are many factors at play that control exchange between the tidal channel and the aquifer, such as the depth of the tidal river, the thickness of the clay layer below the tidal river, possible clogging layers, changing water and salinity levels due to seasonality and tides (Bhuyian et al., 2012), possible salinity gradients in the tidal rivers and possible density driven flow.

At the northern tidal channel, not much exchange between the aquifer and the channel is expected, because of how narrow and shallow the channel has become.

Changes in the manuscript: No change

References

Bhuiyan, M. J. A. N. and Dutta, D.: Assessing impacts of sea level rise on river salinity in the Gorai river network, Bangladesh, Estuar. Coast. Shelf Sci., 96(1), 219–227, doi:10.1016/j.ecss.2011.11.005, 2012.

De Goffau, A., Van Leeuwen, T.C., Van den Ham, A., Doornewaard, G.J., Fraters, B.: Minerals Policy Monitoring Programme Report 2007–2010. Methods and Procedures. National Institute for Public Health and the Environment, Bilthoven, The Netherlands, RIVM Report 680717018, 2012

FAO: Soil Survey of the Ganges-Kobadak Area. ETAP Report no. 1071, Rome., 1959.