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Hydrology and Earth System Sciences
Discussions

# *Interactive comment on* "A three-dimensional palaeo-reconstruction of the groundwater salinity distribution in the Nile Delta Aquifer" *by* Joeri van Engelen et al.

**Anonymous Referee #1**

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This paper addresses the important topic of the groundwater salinity distribution in large-scale (delta) aquifer systems in relation to the palaeo-geographical evolution. The authors use the Nile Delta Aquifer to investigate how different conceptual models affect the simulated present-day groundwater salinity patterns. The results are relevant to comparable systems elsewhere, and the study is rather unique in terms of the large number of model scenarios that was considered. This makes it a valuable contribution, especially because there are few studies of this type. Nevertheless, there is room for considerable improvement, in particular in the way the model scenarios are evaluated and compared.



First of all though, with regards to the Introduction section, you can build a stronger justification for this study by first discussing the studies that have been conducted in other areas (presently starting on page 3, line 25), which demonstrate that over-simplified models of large-scale aquifer systems are conceptually flawed. Then you can bring in the Nile delta system, and argue that there is also a need there to analyze the palaeo-geographical evolution in order to understand the present-day conditions. By starting off with a focus on the Nile straight away, you present it too much as a regional problem, not a scientific analysis that yields outcomes that can be transferred to other study regions.

Moreover, the paper as a whole, but the Discussion section in particular, is a bit of a confusing mix of a number of problems. There is (A) the scientific problem of understanding the evolution of the groundwater salinity distribution in large delta systems over long timescales. This is mixed with (B) the local management problem/question of how much freshwater there is in the Nile delta. And then there is (C) the problem that previous models have assumed steady-state conditions. For a publication in HESS, the local management problem (B) is not the most important. The scientific problem (A) is, and it should be made clear from the onset and throughout the paper that this is the main focus. The implications for the local management problem can be mentioned toward the end (it is especially interesting to note that depending on the conceptualization, the locations where freshwater occurs will differ), but should not feature prominently anywhere else.

With regards to the assumption of the system being in steady-state (C), a considerable portion of the paper is devoted to a comparison between dynamic (i.e., models considering the palaeo-geographical evolution) and steady-state conditions (equivalent simulations for the same geology). It is concluded that the dynamic models are a better fit to the data. But given that the data set has severe limitations (there are relatively few data points, and the quality of the available data is also not assured, at least the paper does not describe the QC/QA procedures), one could wonder if that

is really a such strong criterion. I think a much stronger argument could be made by looking at the time required to reach steady state. This information is not presented for all model scenarios, but in line 28 on page 11 it is mentioned that it took 60 ka for the B-model scenarios. Doesn't this automatically invalidate the steady-state assumption, without having to perform anymore detailed comparisons between the dynamic models and their steady-state equivalents? I am not sure what time is required for the other simulations, but I am guessing it will be on the same order, except maybe for the most unrealistic representations of the delta's lithology. I would encourage the authors to present the timescale aspect in more detail and use it to build the argument against steady-state being a realistic assumption. Much of the detailed comparisons such as those presented in figures 9, 10 and 11 could then be omitted.

This would also have the benefit that the paper becomes more easy to follow, because as it stands, one quickly gets lost in the many different scenarios. The Results section could start with what is now subsection 4.2, which could be expanded and/or merged with subsection 4.4. This would give the reader a much better overview of the actual processes before diving into the more detailed analysis of model performance and freshwater volume.

Page 1 lines 15-16, "observed by hydrogeochemists": No need to suggest a disciplinary bias line 17, "palaeo-reconstruction": This suggests your reconstruction itself is ancient. Choose better wording line 18: Insert "a" between "using" and "state-of-the-art model" line 23: You use both "sea water" and "seawater" in your manuscript. Pick one, and check for consistency. line 29: add "s" to "distribution"

Page 2 line 6: insert "that they were" between "indicated" and "pumping". More generally, the language usage needs some attention, the paper is generally well written, but every now and then it lacks some attention to detail. I will not focus on these issues from this point onward, but the authors should do a careful proofread of their revised manuscript to resolve them.



Page 4 line 31: delete "hypersaline and", the fact that they are hypersaline should not be a reason to discard them. On the next page you talk about hypersaline groundwaters as well (or at least, salinities greater than seawater)

Page 5 line 1: I am not sure if this reasoning holds true. A 1000y old groundwater can still move appreciable distances over a couple of decades if it is near a large well field line 26: Some additional information is required here to explain the choices and rationale behind these 9 different lithological models

Page 6 line 5: Replace "its'" with "its" lines 10, 11: Not sure what you mean by "keeping memory locally". line 15 a.f.: You need to include a map with the model area. lines 23, 24, "as the hills above this height have no important contribution to the groundwater flow": Without the aforementioned map it is hard to assess the validity of this statement. Where are these hills? How high are they? More importantly, what is the recharge and the water table elevation. The elevation of the hill itself is not so important, its hydrogeological characteristics much more so, of course...

Page 7 line 3, "time slices": This sounds like what we would normally call a stress period in groundwater modelling. Why the confusing terminology? And why with a space in the title, and without in this sentence. Please pay more attention to detail. line 12: Replace "announced" with "at" line 22, "100 day resistance" (better would be "a resistance of 100 days" BTW): How sensitive are the modelling results to this assumption? A single value is of course highly unrealistic, and citing studies from the Rhine-Meuse Delta does not provide any justification, because this parameter is just as uncertain and spatially (and even temporally at this timescale) variable there. But you've got to work with what you have, I understand that, but in the end, some sensitivity analysis is required to test to what extent the study outcomes might be affected by this modelling choice. line 31: replace "acquiring" with "achieving"

Page 8 lines 3-6: Did you do this via SEAWAT's density options in the CHD package? A range of 2-18 g TDS/L gives quite a range in density. What value did you adopt? And

again, how sensitive is it?

Page 10 line 7: You could cite the following article here: Sanford, W.E. & Pope, J.P. Hydrogeol J (2010) 18: 73. https://doi.org/10.1007/s10040-009-0513-4 line 10 a.f.: This is somewhat hard to follow and it might be worth adding a sketch that illustrates the principle (could be in a supplementary document). Other authors may choose to adopt this methodology, hence it could be worthwhile doing this.

Page 11 line 19: what do you mean with "behavioural"? And what is the justification for using 0.07? lines 19-21: Sentence does not seem to flow well due to a grammar error, not sure what you are trying to say here.

Page 12 line 3: Not clear what you mean here with "behavioural" line 4: Up until this point the difference between fluvial and marine clay layers has not been explicitly discussed. lines 7, 8: replace nondescript terms like "more 3D patterns are visible in the salinities" and "partly has a conical" with more accurate descriptions lines 24 a.f., "This table also shows...": I could not follow what you are trying to say here

Page 14 line 2 a.f.: I think the point you want to make here is that you can come up with multiple models that fit the observations equally well and yet, the volume of freshwater varies a lot. What do you mean with "The variance in the results should also affect management decisions."? I think the management decisions will not be based on the total volume of freshwater, but on the possibility to be able to extract groundwater in a particular region. See also general remark made before about the relevance of the freshwater volume issue for this paper. I would not start the Discussion section with this paragraph (see next point)

Page 15 line 6: Start the Discussion section with this paragraph, it is much more relevant to a broad readership than local aspects such as the discussion of the total freshwater volume (also see general comment) and flow to Wadi El Natrun.

line 32: Also include a discussion of the representation of free convection phenomena



in your model. The large grid size is prohibitive for an accurate process representation. How confident are you that this does not harm the general conclusions drawn from the model outcomes?

Figure 1: It could just be because of the pdf, but the resolution is very poor. Figure needs an inset showing the location of the area within Egypt/the Mediterranean region. Add north arrow and scale bar! In this figure all areas outside the delta are white, better to make the Mediterranean blue and the desert yellow(-ish).

Figure 2: Somewhere we will need a map with the model boundary. On this map you will need to indicate which part of the model is shown here.

Figures 4, 5: Take the reader by the hand here as the figures are complex. Explicitly mention in the caption that a, b, c and d reflect the salinity classes, and explain the n value.

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