Response to interactive comments from Anonymous Referee #2 on "From days to decades: numerical modeling of freshwater lens response to climate change stressors on small islands" by S. Holding and D. M. Allen

Reviewer: This paper is an interesting study of climate-change induced recharge changes and seawater inundation on a small-island freshwater lens. The study uses the numerical models SEAWAT, HydroGeoSphere, and HELP to simulate recharge and freshwater lens dynamics, all appropriate techniques. The paper is generally well written and concise and the figures and table support the article well.

Due to the uncertainty of much of the available data, the conclusions should be couched in more generalized terms and include a discussion of the uncertainty. Questions about the timing and amount of inundation, method and timing of draining, amount of recharge following the inundation, and geology (effective porosity, storage, etc) suggest that these results might just be one realization of many possible outcomes. It would be good to have a feel for how these results fall into the range of reasonable possible results.

Response: *Yes. We appreciate this comment. This study was not meant to be predictive for specific outcomes, but rather to identify the likely response based on the hydrogeological setting and the mean projected climate state derived from multiple climate model scenarios. A range of results would require significant modelling demand, which is beyond the scope of the study.*

The introduction of the conclusions (11465L27) has been revised to recognise limitations associated with uncertainty: "The model results are inherently uncertain due to uncertainty associated with the input data, model conceptualisation, and stressor scenarios. The greatest uncertainty lies in the simplification of the hydrogeology and the associated parameters. This is largely due to limited studies having been conducted on Andros. However, small islands often have limited capacity for hydrogeological investigations. Therefore, this study was not predictive, but rather aimed to identify the likely response based on the hydrogeological setting and the mean projected climate state derived from multiple climate change model scenarios. To rigorously address uncertainty, a series of models with a range of input parameters and climate scenarios would be required; however, this was beyond the scope of the current study. Within these limitations, the results of the study provide the following conclusions:"

The authors are grateful for the helpful comments and suggestions, each of which is addressed below.

Specific Comments:

Comment 1) Recurrent mention of atolls in the South Pacific seems to exclude atolls in the Central and Western Pacific.

Response: Thank you for bringing this to my attention. The term "South Pacific" has been changed to "Pacific" to account for all regions of the Pacific.

Comment 2) Add a definition of lens thickness. Do you mean 50% seawater concentration? 90% or something else?

Response: The lens is defined based on a threshold salt concentration of 0.4 g/L (presented in 11451L25). For clarity, the following text has been added to the results section (11457L8):

"however, this study focuses on areas considered viable to provide a sustainable water supply, which are defined as having a lens thickness of greater than 2 m and concentration less than 0.4 g/L (Figure 5)"

Comment 3) Each well was screened at 5 m b.g.s., corresponding to the maximum depth of most wells/wellfields on Andros Island. Do you mean screened from the water table down to 5 m bgs?
Response: Yes, all wells and wellfields are open boreholes, effectively screened throughout their length. The sentence 11451L20, was edited as follows: "Each well was screened from the ground surface to 5 mbgs…"

Comment 4) Using salt for rainfall of 0 g/L may be too low. The final simulated concentration underestimates the observed concentration in fig 10. Using a higher concentration for recharge (assuming salt spray on ground, higher rainfall salinity during storms) might be more realistic.
Response: This is an interesting point. The difficulty we foresee would be in determining a representative salinity to represent recharge. The historical water quality data suggest that the recharge is not very salty as the freshwater lens is naturally quite fresh (i.e. around 0.1 g/L salt) (Figure 3). This suggestion has been added to the discussion of the discrepancy between observed data and model results following inundation of the trenches, at the end of Point #6 (11463L6): "In addition, the concentration of recharging freshwater may be higher than 0 g/L during storms due to salt spray, thereby introducing higher salt concentrations at the surface and delaying recovery."

Comment 5) Define running the model to steady state. Do you mean no change in concentration over time?
Response: Yes, steady state refers to no change in concentration or morphology over time. In the first instance of the term steady state being used (11447L8), this definition is added " …both models reached steady state (i.e. no further change in lens morphology) within 20-25 years." Where steady state refers to concentration in the text, the authors feel that this has been adequately explained (11459L15-21): "Dissolved salt concentrations in all of the observation wells reach near steady state between stress periods (only very small changes continue to occur on the order of 10-10 g/L per day). The time to reach steady concentrations is relatively similar in all wells, ranging from 0.5 to 3 years and increasing as the simulation progresses."

Comment 6) You didn't explicitly define "potable" water in the text.
Response: as in the response to Comment 2. Additional text has been added in two places to make this more clear: 11444L11 "The majority of local residents rely on the municipal potable water supply (having less than 0.4 g/L salt concentration), which extracts groundwater…" and 11451L24 "The volume and area of the lens were calculated based on a threshold salt concentration 0.4 g/L or less (representing local potable water guidelines) and porosity."

Comment 7) What is the sensitivity of the recovery results to changing porosity? It seems the timing of the plume migration would be highly dependent on the porosity used in the model. It might be fairer to present a range of recovery times based on a range of porosity given the uncertainty of this parameter.
Response: we did not evaluate the sensitivity of porosity in this study. The effective porosity estimate is based on field studies which provide a small range of values for total porosity (0.1-0.2). This suggestion has also been added to discussion of the discrepancy between observed data and model results following inundation of the trenches, within Point #4 (11462L23): "…therefore, hydrogeological conditions (such as porosity or hydraulic conductivity) at the wellfield may…"

Comment 8) Pg. 11463 Factor 6. Along with possible other storm surges, the passage of other hurricanes undoubtedly provided non-average rainfall to the island.
Response: This is also added to Point 6: "however, it is unknown whether any of these caused an additional storm surge event ….. Regardless, the close passage of other storms would have attributed to atypical rainfall events."

Comment 9) Pg. 11464 Ln 10 Doesn't the hydraulic conductivity control the gradient, not the topography of the land surface?
Response: Based on the limited field data available, the hydraulic conductivity of the northern and southern regions of Andros Island is assumed to be constant. However, higher topography allows for thicker lenses to develop, which in turn results in higher hydraulic gradients toward the coast. The sentence is edited for clarification, as follows: "…the topography of the south is generally lower than that in the north, resulting in a thinner lens and slightly lower hydraulic gradient…"

Comment 10) Pg. 11465 Conclusion 1: Generally not good to add a new thought with a reference in the conclusions
Response: That is true, thank you for pointing this out. The mention of coastal settlements is an attempt to demonstrate the significance of results that are otherwise, somewhat expected (i.e. the greatest response is observed at the edges of the lens). The content has been shifted to the Discussion so that this point may be made in the conclusions. At the start of the Discussion, the following text has been added 11463L12: "The volume and area of the freshwater lens are reduced under stressed conditions, indicating that the lens both shrinks and thins. A significant impact is observed in areas where the lens shrinks (i.e. along the periphery), as most settlements and related infrastructure are typically near the coast on small islands (Ranjan et al., 2009; Cashman et al., 2010). As a result, any changes in the freshwater lens morphology within the coastal zone may affect access and availability of fresh water near the population centres."
The text within the Conclusion has also been amended 11466L1: "The impacts of stressors on the freshwater lens are predicted to occur primarily in areas where the freshwater lens is smaller or thinner, such as the periphery of the lens. As most settlements are concentrated within the coastal zone, even small-scale changes to the freshwater lens morphology in these areas may have significant implications for freshwater sustainability."

Comment 11) Conclusion 5: I would argue that trench systems make it easier to drain the saltwater off the surface than on an island without open trenches even though they provide an open pathway to the water table. On most other islands there is little opportunity to drain off the inundated water so it will get into the lens anyway, just delayed. So the net benefit might be higher to have open trench systems.
Response: This is a good point, although it would depend on the conductivity and thickness of the vadose zone and surface cover. In some instances, inundating water would not reach the water table before becoming diluted from recharge. Other studies do suggest that the transport and capture of saltwater in open boreholes/trenches has a net negative effect in terms of storm surge saltwater contamination, regardless of remedial action. Text has been added to this conclusion to acknowledge the potential benefits of open trenches (11466L17): "Trench-based wellfields may increase the potential storm surge impacts on the freshwater lens, depending on the hydraulic conductivity, the vadose zone thickness, and land cover. However, they also allow for remedial action (such as draining the trenches) to be undertaken which can improve recovery times."

Technical Comments:

Comment 12) Perhaps just a stylistic preference on the reviewers part but a few instances of simpler wording could be used i.e. use “about” instead of “approximately”, delete the word “located” and “situated” throughout as it is generally not needed, use “most of” instead of “the majority of”

Response: The suggested revisions have been made. However, as this is a stylistic comment, some instances of the original wording were retained.

Comment 13) Pg. 11460 Ln 4 change “might” to “would”

Response: text changed.

Comment 14) Pg. 11461 Ln 11 replace ”between” with “compared to” or something similar. Otherwise this can be confused with the physical location between two trenches

Response: text changed as follows: “There is little difference in observed concentrations <u>when comparing</u> the trenches that were drained…”

Comment 15) Pg. 11462 Ln 12 Reword to “The amount of recharge that specifically occurred on Andros Island may have been different during 2004-05.”

Response: text changed.