Authors' responses to reviewer comments

We thank the reviewers and the editor for their constructive feedback on our manuscript. Following are our responses to their comments. Blue indicates our responses, *italics is used for citations from the manuscript*, and ***bold shows implemented changes***. All the lines, figures, or tables mentioned below refer to the revised track changes manuscript.

Topic editor

Public justification (visible to the public if the article is accepted and published):
Dear Authors,

Thanks again for your detailed response to the reviewers' initial comments, and for your patience in enduring our delay in issuing this decision (things predictably slowed down over the holidays). I asked the reviewers to consider your response to their comments and revised manuscript. As you will see, the referees generally felt that you addressed their initial concerns, though some concerns remain. Please provide individual responses to their latest round of comments, and I would appreciate it if you would pay particular attention to addressing reviewer 3's concerns, as I had the same concerns myself regarding the reproducibility of the study's repository/results and the quality of figures.

In addition to the reviewers' comments, here are some additional comments from me, some of which have overlaps with the reviewers' comments.

1) Software Development. With regard to software development, it is difficult to easily discern the specific modifications to CWatM that were undertaken to conduct this study. The authors are encouraged to discuss (and display through a figure if possible) more clearly the modifications and how they fit into the existing CWATM model structure (and its presumably numerous modules). I feel that this is actually rather important for readers to be able to figure out how they might go about extending what you have done (e.g., to a global scale, or to add new types of reuse (which I mention below).

We have revised Figure 1 (Lines 101-104) to highlight the processes added to CWatM by the WTRM. These are now shown in a different fill color. We have also reorganized that plot to enhance readability.

We further revised the Code and Data Availability to provide readers with relevant tools to support using CWatM and the module and data associated with this manuscript

(Lines 638-644).

Please also refer to the response to Ref 3.

2) The quality of some figures is a bit concerning to me--both the image/file quality but also the figure organization/appearance. For example, Figures 3 and 4 are a bit disorganized and difficult to read (i.e., see labels, discern trends). Please see Reviewer 3's suggestions for enhancing figure clarity.
Following this comment and the comment from Ref. 3, we have revised all our plots, particularly Figures 3 and 4.

In Figure 3:

- we have trimmed some of the months to focus on the relevant data,
- we have also trimmed the y-axis so the differences between different scenarios is better captured in the graphs,
- We have improved the graphic language and included labels to indicate better the role of the different components in the graph (Line 350-353).

In Figure 4:

- we have simplified the graphics, including just the wastewater circle (instead of three), and added some straight arrows and numbered labels to account for the interaction with other model components (Line 407-409),
- describing texts are also updated (Lines 372-393),
- a complementary reservoir water circle is added in Figure S4.

3) What parts of the landscape of water reuse options that currently exist are modeled here versus excluded? For example, readers may wonder, is direct potable reuse handled? How about indirect groundwater injection? It would be good for readers to know where this model fits, so they can quickly identify its applicability to their specific research interests. In a sense, this also relates to some initial concerns I had about the lack of discussion of limitations. Please help readers understand what they can and cannot use this model for in a variety of reuse contexts.
The WTRM interacts with CWatM, allowing the simulation of diverse reuse options. In line 203, we have updated some examples: *The basic module has two post-treatment options: river discharge and* ***reuse****. Direct* ***reuse*** *(e.g., for irrigation****, industrial, and potable uses****) is possible using the CWatM reservoirs and water demand routines.*

This assessment focuses primarily on wastewater reuse for irrigation and, to some extent, reuse for livestock purposes (Lines 304-307):

*"The second (S1) and third (S2) include wastewater treatment and reuse without and with urban runoff collection, respectively. The share of urban runoff flowing into the sewers is set as a calibration parameter in S2**. In this case study, we defined sectoral water allocations to limit wastewater reuse to irrigation, with limited use for livestock purposes".***

This is also mentioned in Lines 519-522:

*"Combined with the source-sector abstraction fraction, the modeling of the Ayalon basin has limited the use of treated wastewater for irrigation and livestock to a smaller extent. Other existing uses, like urban landscaping or cooling of thermal powerplants, were **excluded**, as data to incorporate those uses into our module was unavailable".*

We have also added a paragraph suggesting potential uses, which are partially demonstrated in this analysis (Lines 508-510):

"Reservoirs allow storing and transferring treated wastewater, and reusing it in relevant irrigation districts (i.e., by utilizing the CWatM command areas feature). Leakage from reservoirs into groundwater aquifers (see Figure S4) can be used to simulate groundwater recharge with treated wastewater."

Although some additional options (e.g., treated wastewater injection into the aquifer) can be included (e.g., by defining negative values of groundwater abstraction in MODFLOW6), there are currently no variables/processes set in CWatM to represent these processes. Therefore, we do not include them in the current study.

4) Regarding terminology, your revision addressed a lot of my initial concerns, but I do think there are some areas still where defining terms could help. For example, how does wastewater reclamation differ from wastewater reuse? Many readers will not understand whether/how you distinguish between these terms.

We have used wastewater reuse and reclamation interchangeably, as they have a similar meaning. Wastewater reclamation includes collecting, treating, and reusing wastewater, whereas reuse only refers to the last process. We accept that using these two terms interchangeably may confuse the reader, and we replaced the word reclamation with reuse. As such, the paper title has been amended to: *Wastewater matters: Incorporating wastewater treatment and **reuse** into a process-based hydrological model (CWatM v1.08)*.

Many thanks for your submission and for your revision efforts.

Thanks,

Tom

Ref 1:

Thanks to the authors for the re-submission, and for their efforts to improve the manuscript.

Overall, I am mostly satisfied with the revisions (although some corrections to typographical errors are still required). Please find below my response/additional comments on the manuscript, organised with respect to my original reviewer report (i.e. RC1).

1. The authors have done a good job in better describing the three stages of the workflow (i.e. pre-treatment, treatment and post-treatment) and have provided additional clarity on some of the more ambiguous terms previously used (e.g. "user defined collection areas"). The distinction between the "simple" and "advanced" options for the module are now also more clear, and the additional discussion is also helpful. Note that the reference in lines 525-526 should be Jones et al., (2023) [Jones, E. R., Bierkens, M. F. P., Wanders, N., Sutanudjaja, E. H., van Beek, L. P. H., and van Vliet, M. T. H.: DynQual v1.0: a high-resolution global surface water quality model, Geosci. Model Dev., 16, 4481–4500, https://doi.org/10.5194/gmd-16-4481-2023, 2023.]. Also note that the pre-print version of this paper is cited in different places in the manuscript, which should also be updated to the 2023 published paper.

We thank the reviewer for the positive assessment of our revision. The reference and citations throughout the papers were updated.

2. Thanks for the clarification; I interpret this as wastewater generation being simulated by CWatM-WQ with a daily timestep, but read into WTRM as input as an annual or monthly average – is that correct? Also not sure I fully understand why there is not a seasonality component in the estimates of inflow associated with water withdrawals, in addition to S2 which includes a seasonality component as a result of urban runoff. Can you briefly explain?

Wastewater collection is the sum of the collected wastewater generation and urban runoff.

Wastewater generation collection lacks seasonality due to the dataset used in this assessment.

We have better distinguished the newly introduced features of WTRM from those of CWatM, as seen in the revised Figure 1 (Lines 101-104). Generated wastewater is non-irrigation return flows, simulated by CWatM daily. The volume of non-irrigation return flows is a function of water withdrawals for domestic and industrial uses (which depend on water demand and availability) and return-flow fraction.

1/ Water demand and return-flow fraction are model inputs in CWatM, estimated annually or monthly, following a similar approach to the PCR-GLOBWB's (Wada et al., 2011a, 2011b). Annual/monthly water withdrawal is divided within CWatM by the number of days in a calendar year/month.

In this analysis, we have constructed a national dataset based on annual municipal data from the Israeli Bureau of Statistics.

2/ Water availability can limit water withdrawal, thus reducing non-irrigation withdrawal.

In this analysis, as desalination acts as a backstop water source, water availability is not a limiting factor for wastewater generation.

Seasonality in inflows into WWTP originates, in this assessment, from the urban runoff component.

Based on the discussion above, it could be acceptable that wastewater generation in this assessment is based on annual data and lacks seasonality. However, wastewater collection includes, to some extent, urban runoff, which has a seasonal component.

References:

Wada, Y., van Beek, L. P. H., and Bierkens, M. F. P. 2011a. Modelling global water stress of the recent past: on the relative importance of trends in water demand and climate variability. *Hydrol. Earth Syst. Sci.,* 15, 3785–3808, https://doi.org/10.5194/hess-15-3785-2011, 2011.

Wada, Y., van Beek, L. P. H., Viviroli, D., Dürr, H. H., Weingartner, R., and Bierkens, M. F. P. 2011b. Global monthly water stress: 2. Water demand and severity of water stress. *Water Resources Research,* 47(7): W07518, doi:10.1029/2010WR009792.

3. OK, that is now more clear.

4. OK.

5. I find this aspect still somewhat unclear. Perhaps the manuscript could benefit from a more detailed description of how "wastewater treatment service areas" are defined (comment 1). The authors response to this comment makes it sound like these service areas are defined based on river basin borders (and then the model checks if there is a WWTP in that area); and therefore not delineating these zones based on the precise location of wastewater treatment plants? If that is the case, what then happens if multiple WWTPs are located in the same river basin? Apologies if I misunderstand here.

We have now included another map in the Supplementary (Figure S10), demonstrating the two main collection areas (aka service areas) of the *Ayalon* and *Shafdan* WWTPs.

To make the notion of collection areas more understandable, we have included additional explanations in lines 119-121:

*"WWTP service areas (or collection areas) are model input that defines the linkages between the location of wastewater generation (individual grid cells, denoted by l) and wastewater treatment plants (denoted by j)**, namely that the wastewater from all grid cells in a collection area are treated in the associated WWTP (see Figure S10)".***

Further, we elaborate on how we have created the data (Lines 559-563):

*"Two additional challenges are indicated in Table 4, associated with the treatment days and service (wastewater collection) area**. In this study, we rely on a national dataset associating municipalities with WWTPs (see Figure S10; INRA, 2016), yet this data is not available for most countries. Instead, following** Ehalt Macedo et al. (2022), the **wastewater collection areas** can be traced back from the WWTP to serve the nearest, most likely upstream, population centers".*

In the supplementary of Ehalt Macedo et al. (2022) the authors outline three different approaches to estimate the number of people served by a WWTP (P. 4-8 of the supplementary of Ehalt Macedo et al., 2022). Two of the approaches (A2 & A3) rely on the assumption that the grid cells that are closer to a WWTP are more likely to be served by it, and they propose to set a buffer (e.g., optimal size found to be 11 km) around each WWTP to find its population. Based on this approach, it would be possible to trace back the most likely service areas for each WWTP. However, we do not find the description of that approach, and these ideas are within this paper's scope.

<u>References:</u>

Ehalt Macedo, H., Lehner, B., Nicell, J., Grill, G., Li, J., Limtong, A., and Shakya, R. 2022. Distribution and characteristics of wastewater treatment plants within the global river network, *Earth Syst. Sci. Data*, 14, 559–577, https://doi.org/10.5194/essd-14-559-2022, 2022.

6. OK.

7. For clarification, I certainly don't doubt the importance of including wastewater treatment and reclamation in (high-resolution) hydrological models. My comment was more related to the fact that the model has only been applied to a single basin (albeit with various scenarios) that is both water scarce and reliant on wastewater; and therefore find it somewhat difficult to assess the model performance in different

hydrological/socioeconomic settings. But perhaps this comes later, once the additional efforts to upscale the approach to global scale have been made.

We thank the reviewer for the clarification. We also appreciated that comment, as the reproducibility component was not sufficiently developed in the first version of this manuscript. We hope our additional explanations clarify the upscaling potential of our module, and we are planning additional case study applications for the future.

Ref 2:

No comments

Ref 3 (poor reproducibility, poor presentation quality):

The authors have addressed my technical comments. However, the overall quality of the paper still does not meet the standards of GMD. The reproducibility of the study is not clear, considering there is no detailed instructions in the repository.

We thank the reviewer for these insights and suggestions, which helped us to improve the manuscript further. To allow reproducibility, we have taken the following steps:

1/ added into the Code and Data Availability additional references to relevant tools that support readers in using CWatM and the newly developed module in this manuscript, which reads in lines 638-644 as follows:

The CWatM code is provided through a GitHub repository (https://github.com/iiasa/CWatM; last accessed: 15 February 2025), and the model version used for this study (CWatM-Israel v1.06.1) is provided via ***https://doi.org/10.5281/zenodo.13990296 (Fridman, 2024; last accessed: 25/10/2024). Documentation and tutorials of CWatM are available at https://cwatm.iiasa.ac.at/ (last accessed: 15 February 2025).*** *The input data used for this publication, including model settings and initial conditions files, can be downloaded from https://zenodo.org/doi/10.5281/zenodo.13990451 (**Fridman et al., 2025;** last accessed: **26/02/2025**).*

2/ We have updated the dataset associated with this manuscript, by –

- *revising the preview text,*
- *and adding a readme file with details on the dataset content and association between settings files and simulated scenarios (e.g., specific graphs and tables in the manuscript).*

The authors should consider making significant improvements to the presentation quality, particularly in the figures and tables, to enhance clarity. **The issues highlighted below are not isolated to a single figure or table but are indicative of broader presentation quality across the paper. Authors should carefully review and revise all figures and tables to improve the overall quality and readability of the manuscript.**

We have reviewed all figures and tables in the manuscript and included changes to Figure 1, Table 1, Figure 3, and Figure 4 (please see also responses to the editor's comments).

Figure 1:

1. **Add more details to clarify the relationship between the new WTRM and CWatM**. Clearly distinguish what constitutes the original CWatM and what are the new additions in the WTRM.

2**. Ensure consistent font sizes for the same hierarchical elements. For instance, the font size describing processes like "intensive" and "extensive" systems should match the font size of the text within the Figure 1A box**.

3. **Use standard notations such as "(A)" and "(B)" to label subfigures for better readability and consistency.**

4. **Clearly label both "active pond" and "inactive pond" to distinguish between these components in the extensive treatment system.**

5. **Avoid using duplicate number labels within the same plot. For example, the number "1" appears twice for "Pre-treatment" and "Intensive," which could confuse readers.**

Figure 1 is replaced with a revised version (Lines 101-104) where CWatM's original features and newly introduced features are separated using fill color; labels were controlled for size and rearranged, and repetitive numbering.

Table 1:

1. **Improve the structure of the table by making the separation between global and local datasets more apparent. Consider centering and bolding the headers for these two sections.**

2. **Standardize temporal resolution terminology (e.g., "annual" vs. "by year") for consistency.**

3. **Break down rows with multiple datasets into separate rows for better clarity. For instance:**

a. Separate the "wastewater treatment plants database" into three distinct rows.

b. Apply a similar approach to the "groundwater basin and aquifers" row.

In Table 1 (Line 258), we have broken lines that were aggregated together; we have divided the spatial and temporal resolutions into two columns and standardized the terms used to describe each.

On some occasions, we have left some items as an aggregate, e.g., ***Wastewater attributes and technical data***; in that case, we add a brief description of the included variables (usually 2-3 variables) into the data source and comments column, e.g., ***Attributes include wastewater treatment levels, years of operation.***

Figure 3:

1. **Significant improvements are required to enhance readability. For example, it is difficult to distinguish the color difference between the "No wastewater" and "Wastewater without urban runoff" lines.**

2. Revisit the overall design to ensure that line colors, labels, and legends are clearly distinguishable.

Figure 3 (Lines 350-353) was revised to enhance its visual appearance and readability. Particularly,

- the 'No wastewater' line color is now darker,
- we have trimmed some of the months to focus on the relevant data,
- we have also trimmed the y-axis so the differences between different scenarios are better captured in the graphs,
- and we have improved the graphic language and included labels to better indicate the role of the different components in the graph.