RC1: ‘Comment on egusphere-2023-142’, Anonymous Referee #1, 11 Apr 2023

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Referee #1, General comments:

General comments

The manuscript entitled “Developing a tile drainage module for Cold Regions Hydrological Model: Lessons learned from a farm in Southern Ontario, Canada” submitted to EGUsphere introduces and evaluates a new tile drainage module for estimating surface and tile drainage flows using an 8-yr surface and tile drainage data set from a farm in southern Ontario. While the manuscript is generally well written, some important clarifications are needed throughout. Consistent terminology should be applied to soil water and groundwater flow processes. For example, the term ‘soil water levels’ is frequently used but needs to be consistently defined in the overall conceptual model of water flow. In several sections it is unclear whether the authors are implying unsaturated (e.g., matric potential) or saturated (shallow groundwater, Darcian flow) flow conditions. While considerable time is spent on the importance of the capillary fringe, there is an overall lack of discussion focused on the model predictions versus field flows and how they were influenced by annual weather variation or seasonally driven factors. It would also be beneficial for readers to see how the model performs for some signature (large) runoff events (maybe include some snowmelt events since the model accounts for these processes). It is not clear how modeled groundwater dynamics were used to adjust tile drain flows. The abstract does not mention how the module performed for the field data. It also mentions lateral flow to tiles but there is no relevant discussion of the results. Considerable time is spent on introducing the new module in the introduction compared to the relatively short time discussing model effectiveness for the field data. It would be beneficial to present some “next steps” for TDM module development based on the present findings and vision for further calibration/validation and improvement. Overall, the ideas and data presented by the authors are novel and well-conceived. The paper will benefit from a hearty revision. Please refer to line-by-line comments below.

***Response to general comments*:**

We thank the referee for these insightful comments.

Water table terminologies were made consistent throughout the manuscript, and unsaturated and saturated flow conditions were clarified based on the provided detailed comments.

More discussion on the effectiveness of the model in the prediction of tile flow and how seasonality affects tile flows and creates gaps in the growing season was added to both the abstract and results/discussion. In addition, the good match between simulated and observed flows is shown in Figures 4 and 5.

In response to "How the modeled groundwater dynamics were used to adjust the tile drain flow", it should be mentioned that, as discussed in comment #16, groundwater is fully connected with soil water, such that the soil water table and groundwater table are synonymous in this study. It means that when groundwater fluctuates, we will have exactly the same fluctuations within the soil water table (WT or soil saturated storage, SSS). Fluctuations in WT affect the tile flow since tile flow here is calculated based on the Hooghoudt (1940) equation and using soil water table elevation. So, a change in groundwater table causes corresponding changes in soil water table and tile flow. The terminology "water table" is adopted throughout the manuscript now to refer to this combined saturated storage.

Finally, some next steps for improvement of the TDM module were added to the end of the conclusion section. Our responses to detailed comments are below.

Referee #1 detailed comments and our ***responses*** to comments are below (the line numbers in our responses are for the annotated or the track-changes version of the manuscript).

1) Comment:

The tile drainage module's effectiveness for predicting field tile flows should be added. A stronger concluding sentence based on the implications of your most significant finding is suggested. Line 27: "Water level patterns". Clarify 'water levels' here and throughout, i.e., groundwater (saturated/gravity-driven flow) or soil-water under tension (unsaturated, under tension/Richard's eq.)

***Response*:**

Lines 23-26: A sentence about the effectiveness of the module in the prediction of field tile flow was added.

Lines 36-44: A sentence was added about the main findings of our research: "A novel aspect of this module is the use of …"

Lines 36-38: The sentence about "Soil water level (elevation head) histogram" was deleted.

2) Comment:

Line 116: Clarify "soil water level". Saturated or unsaturated conditions?

Response

Line 127-128: It was changed to "water table position".

3) Comment:

Lines 118-126.

Response

We assume that the reviewer is referring to the use of "water level depth" here. The term "water level depth" was changed to "depth of saturated water" (Line 131).

4) Comment:

Line 147: Does "pressure head" refer to groundwater elevation head?

Response

Line 169-170: "pressure head" was changed to "groundwater/soil water elevation head"

Methods

5) Comment:

Line 158-159. Tile water may include shallow groundwater flows not exclusively “infiltrated” from the study field.

Response

Lines 184-186: Changed to “The tile network collects infiltrated water from about 75% of the field (~ 7.6 ha), but may also receive lateral groundwater flow from neighboring fields.”

6) Comment:

Line 166-167. Clarify the last sentence more. How are surface and groundwater isolated for measuring and sampling if they outlet in the same area?

Response

Lines 199-203: This has been clarified in this section. “However, surface water or elevated soil moisture conditions are not observed in this topographic low during smaller events or dry periods of the year, suggesting that this saturated ponding is not in a groundwater discharge zone. Although surface ponding is observed in the topographic depression within the field, water discharges freely at the opposite end of the culvert, facilitating the measurement of flow.”

7) Comment:

Lines 188-191: What’s the size range of HRUs that can be modeled?

Response

The size of TDM HRUs can be as small as the size of a single tile pipe (e.g., 1 m) times the pipe spacing (which was 14 m in our case study region), and as large as entire tile networks within a given farm or study area. We have added this sentence in L224 -226.

8) **Comment:**

Line 207: “…soil water level (water table position). Please clarify. Is soil water level synonymous with water table elevation head?

Response

Line 256: We changed the “…(water table position)…” to “…(water table elevation head)…”

9) **Comment:**

Line 232: 31.7 km seems far for assuming similar precipitation patterns.

Response

Lines 287-291: We have clarified the text in the paper, which was unclear in the previous submission. Rainfall was measured at the study site. Hourly snowfall was obtained from nearby stations as far as 31.7 km away. These snowfall observations were tested for local application using periodic on-site snow surveys and found to be similar. As snowfall varies far less over space than rainfall this provides reliable precipitation inputs to the model.

10) **Comment:**

Line 265: Clarify “soil water level observations”

Response

Line 327: We now consistently used “water table” which is the water level elevation we measured using an observation borehole.

11) **Comment:**

Line 283: Clarify “water level” in conditions 3. Groundwater level?

Response

Line 345: “water level” was changed to “water table”

12) **Comment:**

Figure 2. The schematic looks good, but it is slightly hard to follow.

Response

A legend was added to Figure 2, which makes it much clearer now.

13) Comment:

Line 322: “...water level from soil moisture”. Groundwater elevation head level?

Response

Lines 383-385: The sentence was revised as: “To calculate a saturated storage (water table or groundwater elevation head level) from soil moisture calculated by the model, a threshold soil moisture content (sm_t) is defined, …”

14) Comment:

Line 324: “...and was calculated as...”

Response

Line 387: The sentence has been revised.

15) Comment:

Line 335: How is ‘bottom of the soil’ determined? Same as tile depth?

Response

Line 399: The bottom of the soil was determined based on the soil cores and assessment of the depths of layers with significantly smaller hydraulic conductivities and finer grains compared to the shallow soil layer. In TDM, the soil bottom layer doesn’t have to be completely impermeable; it can be set as semi-permeable with adjustable permeability.

16) Comment:

Line 362: $G_{y,l}$ is not defined in variable explanations. How were changes in groundwater elevation used to modify tile drain flows?

Response

Lines 424-425: A sentence was added to define $G_{y,i}$. The tile flow is calculated using the Hooghoudt equation (Hooghoudt, 1940) based on water table elevation in each time step (section 2.4.3). So, when seasonal groundwater/soil water table changes are added to the system, it will affect the tile flows accordingly.

17) Comment:

Line 387: Five different methods

Response

Line 452: This was corrected.

18) Comment:

Line 411: Suggest combining results and discussion

Response

The manuscript presents the results obtained for several hydrological variables, including tile flow, water table, surface flow, and total flow, as well as supplementary results and analyses, such as the results of a sensitivity study for the tile flow, soil water table dynamics, capillary fringe thickness and drainable water. For this reason, we decided to have the discussion section as an individual section as is normal practice in most published papers in hydrology. In the discussion section, we focused on discussing the results, describing the key controlling mechanisms of tile flows and the effect of groundwater seasonality.

19) Comment:

Figure 4. Add a period after “Figure 4”. This graph looks good. Maybe enlarge somewhat if possible. SWE needs to be defined in the caption.

Response

A period was added after “Figure 4” (Line 488). SWE was defined in the caption. Figure 4b, with the shorter time interval, was added.

20) Comment:

Figure 5. On the y-axis, you have “Groundwater/soil water level (mm)”, assuming they are indeed synonymous. In the caption, however, you refer to it as “water level in the soil”. As stated, please revise this terminology consistently throughout to avoid confusion.

Response

We revised the caption to “... Saturated storage/ water table ...”. Also, Figure 5’s left vertical axis title was revised.

21) Comment:

Lines 456-457. Did you evaluate the seasonal or interannual variability of model predictions? What about looking at other times when there was either good or not-so-good agreement between observed and modeled flows?

Response

As can be seen in Table 2, the performance of the model in predicting tile and surface flows, as well as soil water table, was evaluated for the entire simulation period. In Lines 533 to 536, we discussed the reasons for uncertainty in the prediction of cumulative surface flow and total flow (in Figure 6), which partly occurred due to the blockage of the tile pipe between 2017 and 2018. The main goal of the TDM module was to simulate tile flow and water table, and we can see in Table 2 that the model performance in the prediction of tile flow and the water table was significantly better than in the prediction of surface water flow. On the other hand, Figures 4 and 5 show an acceptable match between observed and simulated tile flow and water table, and we can see that TDM was successful in capturing large seasonal water table fluctuations, their corresponding seasonal gaps in tile flow, and the sudden drops in water table.

We believed that by calculation and implementation of $G_{y,i}$ or annually variable seasonal groundwater fluctuation coefficient, we evaluated and considered the seasonal or interannual model prediction capabilities.

22) Comment:

Table 2. Add a period after “Table 2”. Add time period over which modeling represents. Assuming it included all events over the monitoring period? What about interannual variation?

Response

A period was added after Table 2. The performance coefficients in Table 2 are calculated for the entire simulation period. Since the observed soil water table data did not cover the entire simulation period, we were not able to evaluate the interannual variations in the performance coefficients for soil water table. So, we decided to evaluate the coefficients for the entire simulation period only.

23) Comment:

Add a footnote explaining model performance acronyms (NSE etc.).

Response

Footnotes explaining 5 model performance coefficients were added to Table 2.

24) Comment:

Figure 7a,b: Are these best fit lines or model predictions? Please clarify.

Response

The lines in Figures 7a and b are the model predictions. We added to the figure caption that the lines are the model predictions.

25)Comment:

Figure 8. Add period. Define LON.

Response

These changes have been made.

26)Comment:

Figure 9. Clarify “soil water levels” in the caption. Matric potential?

Response

These are histograms of soil saturated storage (SSS) or soil water tables (SWT). We extract the soil water table from the time series and plotted them as a histogram.

27)Comment:

Line 552. It is not clear if groundwater is being used to adjust tile flows. How are SWL, groundwater elevation head and matric potential related over a range of soil moisture contents?

Response

As mentioned earlier, the groundwater at the site and in neighbouring areas are directly connected to soil water in the site, both water sources contributing to saturated conditions in the water table. So, groundwater fluctuations in neighboring areas directly affect the water table in tile drained area and correspondingly affect the tile flow rate. That is because the tile flow is calculated based on Hooghoudt (1940) equation (Eq. 1), as it is discussed in Section 2.4.3. According to Hooghoudt equation, the tile flow rate is proportional to the difference between the water table elevation and tile pipe elevation. In TDM the regional groundwater fluctuations are adjustable and defined as a sine function (Eq. 4). So, in TDM we can adjust the groundwater fluctuations amplitude in each separate year [using $G_{y,i}$ in Eq. 4] to have a better match between the observed and simulated tile flows and water table time series. This means TDM can adjust the seasonality in groundwater table in neighboring fields in order to have a better match between tile flows and soil water tables.

Additionally, eq. 3 in section 2.4.4. presents the relationship between soil moisture and water table in the soil.

28) Comment:

Line 554. Suggest revising the term “opportunity time” to residence time or a similar term

Response

Line 644: We changed it to “residence time”.

29) Comment:

Line 579. Clarify SWL (matric or elevation head?)

Response

Line 670: It stood for soil water level (SWL), but, it was revised to water table (WT) or soil saturated storage (SSS) according to Eq. 3 and Table B1 (Appendix B).

30) Comment:

Line 592. “soil water level depth”. Clarify

Response

Line 683: It is soil water table (SWT) depth, as it is clearly mentioned in the text (Eq. 3 and Table B1).

31)Comment:

Line 599. Is one field representative of catchment scale hydrology?

Response

Lines 690-691: What we meant here, is that since the CRHM platform can be used at catchment scale, the TDM within a large catchments can be considered as one or more HRUs and the interactions between TDM HRUs with other HRUs within the catchment can help us to have a better idea about the effect of tile drainage on other parts of the catchment.

Another important point is that by implementing the groundwater table seasonality within the module, we consider the effect of catchment scale groundwater fluctuations within the module. However, given the potential for confusion, we removed the words “at the catchment scale” from the sentence.

32)Comment:

Lines 624-629. More discussion should be added here on groundwater dynamics and relationship to capillary fringe and tile flows. Including some recent references and how they relate to your findings would also benefit the paper.

Response

Lines 717-730: More discussion has added about this topic with four new references added.

33)Comment:

Line 632. Modeling flows in one field does not capture the myriad of conditions found in larger, more complex catchments. Also, how does the model handle the high variability of saturated hydraulic conductivity, porosity and other spatially variable inputs? What about preferential flow to tile drains? How was this handled for the field site and was it a substantial component of overall flow (macro vs. micropore flow?).

Response

Line 733: To simulate large catchments with CRHM the catchment needs to be divided into a series of HRUs depending on the complexity of the catchment characteristics. We have revised the sentence to indicate that this work has been done for a single field site as a first step. Adding layer complexities and preferential flow paths in TDM are some of the next steps envisaged in the future as the TDM is adapted for other sites and soil textures such as clay soil, when preferential transport into tiles plays a more significant role.

34) Comment:

Line 656. Do you mean the depth of tile drains below the soil surface?

Response

Line 759: We revised the end of the sentence to "… and the depth of tile drains below the soil surface,"

RC2: 'Comment on egusphere-2023-142', Responses to Anonymous Referee #2, 1Jun2023

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__Referee #2__ **general comments** and our *responses* to comments are below (the line numbers in our responses are for the annotated or the track-changes version of the manuscript).

1) Comment:

The topic is highly relevant and there is definitely a strong need to develop drainflow concepts and modules for catchment scale modelling. The proposed module seems reasonable builds on many sound observations regarding drainflow generation, although it depends on parameters that are typically not know in time or space outside the specific study site.

Response

In answer to the next comments we discussed how we can evaluate the required TDM module's parameters for areas out of the study site.

2) Comment:

I am quite sceptical about the observational data behind the model validation. Primarily because there is only one field site. Secondly, the water level and soil moisture is measured only in one location and on the edge of the field. Drainflow generation is highly variable from fields to field and within fields. I don't see how a single field drainflow record can validate a conceptual drainflow component of a model applicable to cold regions in general. In Denmark, we have recently collected a dataset of 45 timeseries of drainflow from tiledrained clay-dominated fields across the country. They display a large spread in drainfractions (relative to recharge or precipitation) and drainflow dynamics. I fear that the model developed here needs to be confronted with data from more than a single field to prove its general applicability.

Response

In this study we presented the preliminary version or the first test of TDM module and based on the available water table and tile flow data from a single site. The next phase of model development will test the module for more study sites and soil types as well as with more water table data from different locations within the site. We are aware of that the data from a single field cannot adequately validate a module, but we have learned a lot in this study and in a single site about how hourly simulation time steps, regional groundwater table fluctuation and simplifying the capillary fringe parameters can work well in a real condition. However, as we mentioned above, we will test the module with more study sites and soil types in our future studies.

We have clarified this in the final paragraph of the conclusions section:
The TDM was developed as a first approximation from a single field site. Given this limitation, it is not yet widely applicable across multiple field sites. However, the development of this module has provided valuable insight into the potential for hourly simulation time steps, as well as the importance of regional water table fluctuations and simplifying the capillary fringe parameters within models in some landscape types. Future work includes building on the model and adapting it for different soil textures such as those in clay soils, where preferential flow can have a strong impact on soil saturated storage and tile flow. Also, explicit representation of unsaturated flow will be needed to enable the use of the model regions where groundwater is disconnected from surface water, as commonly happens in semi-arid agricultural regions.

3) **Comment:**

Also, during the argumentation for the TDM module assumptions, it is argued that “, which presumes no surface ponding, an assumption that generally holds at the study site (Eq. 1), where water ponds only during very wet periods and on a small portion of the study site” and again in line 307-308”. But the TDM module most be more general than just fit for the specific study site. It is intended to be applied across Canada and cold regions beyond.

Response

The reviewer is correct. As noted in the previous comment, the TDM developed here was initially done for a single field site to improve our understanding of process and ability to test this knowledge with a robust data set. However, the next phase of model development will be to build on this early work to make it applicable across multiple landscapes. The reason for using only the equation for the condition with no surface ponding for the tile drainage was to keep the preliminary version of the model very simple.

4) **Comment:**

Also, several of the parameters required might be know at this particular site (e.g tile drain spacing, CF thickness, CF drainable water, seasonal factor, maximum soil moisture and capillary fringe thickness) but how would they be parameterized in general when applied in a large-scale hydrological model?

Response

Some parameters such as drain spacing are usually publically available from governmental or non-governmental relevant organizations' websites. But for some others such as CF thickness, CF drainable water and maximum soil moisture, some initial values can be extracted using the soil texture as we discussed in our response to comment #12 from referee #2 (specific comments). We can use these extracted values for the parameters as initial values in the model. Then, these initial values can be adjusted during model calibration or verification by matching the observed and simulated tile flows and soil water table time series. The seasonal factors for each year also can be adjusted during model calibration/verification. Also, for the large-scale hydrological model the area can be divided to smaller HRUs and the parameters are defined and verified for each HRU separately. Since most CRHM parameters describe physically based modules, they are physically identifiable and measurable. CRHM, without tiles, has been successfully applied to large agricultural areas in the Canadian Prairies with parameterization of each HRU from soil textural, land cover, drainage and topography maps and satellite data (Spence et al., 2012, HESS).

5) Comment:

The list of parameters needed to parameterize the TDM shows how many parameters are needed and most of them needs to be calibrated/adjusted. It seems to be a very poorly constrained concept, given that a single drainflow time series is used to estimate all the parameters, and that such time series are typically not available outside dedicated study sites. Table 1 should include some consideration on how parameters would be obtained outside the study site and in lack of observational data.

Response

In general, model parameter setting in CRHM is done without calibration, following the Deduction, Induction, Abduction approach outlined by Pomeroy et al. (2013). As most parameters are physically identifiable and measurable, they can be determined from available geospatial datasets. Some that are not can be abducted from research basins and sites such as this one to biogeophysically similar basins. This is described in Pomeroy et al. (2022). There are many ways to identify parameters in this model application. To estimate the TDM parameters other than with drainflow time series, we can also use either the water table time series or soil moisture time series. Soil parameters can be estimated using the soil grainsize distribution or soil retention curve (if it is available). The seasonal factors for each year in this study area were evaluated by matching the general trends of the simulated tile flow rates and soil water table with the observed time series. To be able to adjust the seasonal factor in each year we need to have adequate amount of observation in each year, but these could be transferred to similar sites and catchments if needed.

In Lines 454-464 We have mentioned some sentences on parameter estimation techniques and how they were further adjusted to local conditions.

6) Comment:

Also, a sensitivity analysis of all parameters would be relevant to better understand what drives drainflow generation in the module.

Response

The key parameters that control the tile flow rate and water table in the soil and were the main focus of this study were the capillary fringe drainable water as well as the capillary fringe thickness. So, in section 3.5 (Figures 7 a and b) we analyzed the sensitivity of the total tile flow to these two key parameters. The sensitivity of the tile flow rate to other parameters such as soil hydraulic conductivity, tile spacing, tile depth have been analyzed in previous studies through development and application of Hooghoudt equation (Hooghoudt, 1940).

7) Comment

It is stated that " However, field soil water level observations show evidence of annual groundwater level periodicity/fluctuation (Rust et al., 2019) that are sinusoidal in nature and cannot be neglected"

But how will this observation and the described method for accounting for annual groundwater level fluctuations be transferable to other sites? Some other sites may have very limited connection to groundwater and some more than the study sites used here.

Response

The reviewer is correct. Indeed, the annual periodicity in groundwater tables is something specific for each site and should be evaluated for each individual study site.

In this initial iteration of the model, we demonstrated the importance of including this variable, as it can be important in some catchments. In areas that are not connected to groundwater, output from the soil is mostly through evapotranspiration or tile drainage, and the water table fluctuations are more controlled by the action of tile drainage. In such cases, we could adjust the seasonal factor for each year so that the general water table fluctuation trend would match observations.

As it is described in Appendix C, the annual periodicity in water table elevation in the groundwater layer is simulated by adding a sine function with annual wavelength to the simulated water table. The intercept and amplitude of sine function are separately adjustable for each year. In model verification step we adjusted the sine function parameter in order to have the better match between general trends in annual oscillation in simulated water table.

8) Comment:

You seem to calibrate the groundwater contribution year by year, which would make it impossible to apply the approach outside fields where drainflow and water levels are already measured.

Response

As we discussed in Appendix C, to consider the water table fluctuations in the groundwater layer, we need to simply adjust the sin function parameters for each year. To adjust the sine function intercept and amplitude we need to compare the sine function to the general trend in observed soil water table time series. Or we can simply calibrate/verify the sine function parameters along with other parameters during model adjustment.

9) Comment:

I am sorry to be critical here, but if you need drainflow and water level measurements for a specific field site in order to parameterize the model, how can it predict drainflow elsewhere?

Response

The objective of the modelling here is to better understand and diagnose the sub-surface hydrological system in tile-drained fields and catchments. This does not preclude applications elsewhere, as have been demonstrated with CRHM. Since TDM is a physically based module and works based on soil physical and hydraulic concepts and laws, for areas with no observed tile flow and soil water table we can evaluate the module parameters based on the soil characteristics which can be assessable based on soil grain size distribution or soil water retention characteristic curve. Based on the evaluated soil parameters and other input hydrological component, the module can assess the tile flow rate and soil water table time series. However, we strongly suggest to compare the model results with the observed tile flow or soil water table time series or sparse data.

10) Comment:

Given the ambition of incorporating this model in the CRHM for large scale applications, I feel that the model development is based too much on a single study site and cannot be validated sufficiently with data from just this one field. In addition, there is not enough consideration on the number of parameters required and how these would be estimated outside the study site.

Response

The referee has made a good point. The module development was based on a single study site and that was because it was our first step through developing a tile drainage module with time steps smaller than daily, with assessment of soil water table position (soil saturated storage) based on the calculated soil storage and by considering the regional groundwater table fluctuations. We faced many challenges in implementing all these new assumption and simplification in the module and at this stage we needed just a preliminary step, to prove that this approach works for a real field site. Definitely, as we previously mentioned, we will improve the module and make it applicable for broader range of soil types and field site hydrological conditions, in our future works. This has been noted in the revised paper.

Referee #2 specific comments and our responses to comments are below.

1) Comment:

L17: rephrase “enables creating”

Response

Lines 17-19: It has been rephrased.

2) Comment:

L22: It is claimed that the evaluation is “A robust multi-variable, multi-criteria model performance evaluation strategy” but it is based on XXX a single …

Response

Lines 23-26: We deleted “robust” from the sentence to show that the approach was just a preliminary step or just a start to develop a multi-variable and multi-criteria approach in simulation of tile flow.

3) Comment

L25: What does “moisture interactions” mean?

Response

Line 33: By using “moisture interactions” we meant the sending and receiving of the moisture between root zone and groundwater.

4) Comment:

L110-111: “Thus, to provide reliable estimations of water from farmland via surface runoff and tile 111 flow, models must be able to predict soil moisture and the soil water level accurately”

Response

Lines 126-128: the sentence was rephrased to “Thus, to provide reliable estimations of water <u>loss</u> from farmland via surface runoff and tile flow, models must be able to predict soil moisture and the soil water table position accurately (…”

5) Comment:

L125: consider rephrasing “appreciably”

Response

Lines 141-144: the sentence has been changed to “It has also been shown that despite the presence of tile drains, the soil above the tile may not drain all gravitational water following an event and may remain at or above field capacity (…”.

6) Comment:

L112-139: I cant help noticing that most of the literature is from the 1970’ies. Is this really the most recent developments within his area?

Response

This section of reviewing the literature review is focused on fundamental equations and theories about tile drainage and tile flow that were developed during this period and not significantly changed or improved in recent years to our knowledge. More recent studies are mostly utilizing numerical models based on these fundamental theories.

7) Comment:

L166: How do you know that this is not as groundwater discharge zone?

Response

Lines 197-201: The sentence has been revised to “Water tends to accumulate in a topographic low in the field, in front of the field outlet during snowmelt or high-intensity rainfall events, presumably due to either surface runoff or return flow (see ponded area, Fig. 1b). However, surface water or elevated soil moisture conditions are not observed in this topographic low during smaller events or dry periods of the year, suggesting that this saturated ponding is not in a groundwater discharge zone.”

8) Comment:

L199-201: Tile drains are typically used in clay dominated soils, why is it meaningful to develop a drainage model only for coarse textured soils?

Response

Although it is indeed true that tile drains are typically used in clay-dominated soils, they are also found in fields with imperfect drainage, such as many landscapes found in the Great Lakes and St. Lawrence regions (e.g. Michigan and Vermont, USA and Ontario, Canada). Less is known regarding tile drain hydrology in these landscapes relative to those found in clay soils. For this reason, as well as the availability of a detailed data set, this landscape type was chosen for our pilot study. Next steps for this work will include testing and adapting the model for clay-dominated landscapes.

This has been added to the Introductory section:

Lines 161-167: "In this study, a new tile drainage module was developed and incorporated within the physically based, modular Cold Regions Hydrological Modelling (CRHM) platform (Pomeroy et al., 2022) to enable hydrological simulations in tile-drained farm fields in cold agricultural regions. As a first iteration, the new module was developed for a field with sloping ground and loam soil with imperfect drainage. Such landscapes are common in the Great Lakes Region (e.g. Michigan and Vermont, USA and Ontario, Canada) and tile drainage in such landscapes has not been as widely studied as it has been in clay-dominated soil."

9) Comment:

L212: How is drain flow measured in a pipe if the outlet zone is typically flooded (figure 1)?

Response

Our revised manuscript provides more clarity on how things were measured and why (Lines 256-275). Briefly, although water ponded within the field, it generally flowed freely through the surface culvert, facilitating the measurement of flow. However, both depth and velocity were measured within the culvert to permit robust measures of flow. This has been noted in several locations throughout the manuscript.

10) Comment:

L253: delete “specific”

Response

Line 312: it was deleted.

11) Comment:

L253-254: How would these site-specific data (“information about the tile network, such as the tile depth, diameter and spacing”) ever be obtained outside the particular site you investigate here?

Response

Information regarding site-specific details regarding tile depth, diameter and spacing may be obtained directly from landowners or can be estimated based on standard design and installation guidelines for the region. This has been added to the paper. Moreover, in many regions, such site-specific information about the tile drainage network is freely available on the relevant organizations’ websites (example, LIO in Ontario: https://geohub.lio.gov.on.ca/documents/cf961d62ee1345c7b191808c9d60a4d7/about).

12) Comment:

L255: Are “CF thickness and CF drainable water” model parameters? And how are they obtained?

Response

This is described in section 2.5. We have now noted this in the paper in response to the reviewer comment (lines 317-318). We evaluated an initial value for CF thickness and CF drainable water using soil texture based on the relationships presented by Twarskawi et al. (2009). These authors introduced CF thickness as “pressure head at field capacity”, and CF drainable water can be assessed based on “saturation at field capacity”. These initial values for CF thickness and CF drainable water were estimated using the soil texture and the relationships presented in Twarskawi et al., (2009). Then, through verification of the model and matching the model output and the observed soil water table and tile flow, the CF thickness and CF drainable water parameters were adjusted. This process is described in Section 2.5.

13) Comment:

Line 465: perhaps also indicate statistics based on daily values, this might be more comparable to most other studies.

Response

According to the reviewer’s comment we calculated the performance coefficients based on the daily time intervals and added them in Table 2. However, the daily performance coefficients except for NSEs for surface flow and total flow did not change substantially. The higher values of daily RMSE (compared to hourly ones) is related to the units.

14) Comment:

L606 sec. 4.2: Given this importance, how would this seasonal pattern of groundwater be estimated outside the study site? Would this not require a “real” transient 3D groundwater flow model?

Response

As we presented in section 2.4.5, because based on the given references, we knew that the water table annual fluctuations in the groundwater layer usually follow a sine function pattern, we simplified the approach and simulated this seasonality using a sine function. The sine function’s amplitude and intercept parameters are adjustable and can be evaluated during model verification/calibration. Verification/calibration can be done by matching the observed and simulated water table (including that in the soil layer) and tile flow rate. It is possible that this can be improved upon in future using a 3D transient groundwater flow model; however, the simple sine function used here provided a good first approximation for the development of this module. This approach is more efficient in dealing with a small study site, where we do not have sufficient information regarding groundwater in the neighboring areas.

However, for regional scale modeling, it would be more reasonable to have an evaluation about the groundwater annual fluctuation by running a 3D groundwater model in advance and use their outputs within TDM module.

15) Comment:

L632: I would not say that it is tested for catchment-scale simulations. It has only been tested for a single field scale site.

Response

Line 710: “catchment-scale ” was changed to “field scale site”. The respected reviewer is right, however the approach and methods we used here can be used for wide range of similar study site with almost the same conditions but definitely this version of TDM does not cover all types of sites with different soil types and hydrological conditions.

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