Responses to the comments from Referee #1 regarding manuscript number egusphere-2023-142, entitled "*Developing a tile drainage module for Cold Regions Hydrological Model: Lessons from a farm in Southern Ontario, Canada*", authors: Mazda Kompanizare et al.

The numbers on our responses to the referee's comments are based on the latest annotated version of the manuscript.

General comments

The authors effectively addressed many of the reviewer comments in their revision to improve the manuscript's clarity, however considerable revision is still needed before publication. Please refer to line-by-line comments that follow.

Abstract

1)Comment

Line 12. "…extensively in [poorly drained] agricultural lands…" Suggest adding 'poorly drained'.

Response

Line 13. It was added.

2)Comment

Line 16. Clarify 'runoff'. Surface, subsurface, both?

Response

Line 17. It was changed to "… agricultural surface and subsurface runoff."

3)Comment

Line 26. "Shorted" should be 'shorter'

Response

Line 28. It was corrected.

4)Comment

Line 25-29. Consider condensing this sentence, a bit hard to follow

Response

Line 27-31: The sentence was shortened.

Introduction

5)Comment

The introduction is still long and could be more concise.

Response

This section has been condensed.

6)Comment

Lines 45-50. Lowering the seasonally high water table in poorly drained fields is the main function of tiles drains

Response

Line 50. We added "…lower the seasonally high water table in poorly drained fields, …" to the sentence.

7)Comment

Line 61. "…that can represent tile drainage". Consider being more descriptive re: tile drainage…what type of flows, matrix? Gravitational? What about surface runoff?

Response

Line 66-71: The sentence was revised and some more details were added.

8)Comment

Line 76. "Since the use of tile drainage has become popular… ". Hasn't tile drainage been used extensively for decades? Do you have any recent tiel adoption trend data specific to Canada that you can cite?

Response

As presented in the study by Kokulan (2019) "Although tile drainage has not historically been used in Canadian Prairies, an increasing frequency of multiday spring and summer storms in these regions (Shook and Pomeroy, 2012) has caused farmers in provinces such as Manitoba and Saskatchewan to

install tile drains at an accelerated rate to tackle the unprecedented waterlogging conditions in their crop fields (Cordeiro and Ranjan, 2012; Kokulan et al., 2019a)." Tile drain usage is also increasing in the Great Lakes region (OMAFRA, 2023; https://geohub.lio.gov.on.ca/datasets/ontarioca11::tile-drainage-area/explore?showTable=true), particularly in fields that are imperfectly drained such as the study field.

Lines 83-84: The relevant references were added.

Lines 1052-1054 and 1106-1108: Two references were added to the reference list.

9)Comment

Line 100. You mention catchment scale but your study is at the field scale, please clarify whether the aim of CHRM-TD is catchment or field scale.

Response

We thank the reviewer for their comment. In this sentence, we were referring to the PDF-based numerical models, which can be used in both field and catchment scales and not specifically about CRHM-TD. In response to the earlier suggestion to shorten the introductory section, we have removed this paragraph.

10)Comment

Lines 104-108. What about the hydraulic gradient?

Response

Line 112-113: we added "…hydraulic gradient …" to the sentence.

11)Comment

Line 110. Suggest changing "Many" to 'Some studies'. Also some of the references cited are quite outdated.

Response

Line 119: "Many …" was removed. The references mentioned here are some of the first ones considering drainable water in tile flow calculations.

12)Comment

Line 140. Integrate the last sentence with the previous one.

Response

Lines 145-149: The two sentences have been integrated.

13)Comment

Line 154-155. "…which are increasingly being artificially drained". Citation?

Response

Lines 164-165: Three references have been added.

14)Comment

Line 162. Soil type or series, not texture.

Response

Line 172: It was revised to " Soil type …".

15)Comment

Line 192. If snowmelt processes were accounted for they should be better explained. How was melting estimated? What about infiltration with partially frozen soils?

Response

This section has been rewritten. Our previous submission included a section that described the capabilities of the CRHM platform and later mentioned the modules used to create a CRHM model for this study. This has led to confusion, so we have removed references to modules not directly deployed in the current study, and we have referred the reader to Pomeroy et al. (2022) for a more comprehensive description of CRHM's capabilities, including those within and beyond the scope of this study.

16)Comment

Line 197. "Water quality" needs further clarification. What specific nutrients? Sediment?

Response

Lines 209-210: The sentence was deleted.

17)Comment

Line 223. Preferential flow is likely an important mechanism at your site since the texture is a clay loam. Preferential flow even occurs readily in silt loams. Maybe just state that you did not model it for this study and will be assessed in future studies?

Response

We agree with the reviewer that preferential flow can be highly important in both clay loams and silt loams. However, we used hydrograph analyses (Macrae et al., 2019) and conservative tracers (electrical conductivity and major ions, as well as temperature) over multiple years (Pluer et al., 2020) and found minimal preferential flow at this site as well as other similar sites. For this reason, preferential flow was not included in this study. However, we will certainly continue exploring this transport mechanism in future studies. This statement is retained in the revised manuscript (Lines 238-241).

18)Comment

Line 227. Our research shows that soil freezing still happens with snow cover, with depth and extent depending on snowpack depth and other radiative factors.

Response

We agree and have modified our sentence to reflect this. We have improved our justification of why we chose to exclude freeze-thaw here. "Freeze-thaw of soil can occur in the study region, leading to partially frozen soils. However, the extent of freezing can differ with snowpack development and other radiative factors. Data collected over an 8-year period at this site found soil freezing was restricted to brief periods and such freezing never extended below 10 cm depth. Such shallow depth of freezing does not meet the criteria for frozen soil infiltration where the influence of ice in soil pores must be considered in soil water movement calculations (Zhao and Gray, 1999). Consequently, freeze-thaw processes were not deemed critical for representation in our modelling study, though they are a CRHM platform capability and could easily be added should frozen soils occur."

19)Comment

Line 241. How good was the regression relationship for the rating curve?

Response

Regression relationships were $R^2 > \sim 0.5$. This is because during high-flow periods, water levels would rise in our access pipes due to impeded flow downstream. However, the depth-velocity sensor was largely functioning during such periods. This has been mentioned in the paper.

20) Comment

Line 245. You mention "forcing" with other covariates but do not present or discuss forcing data. I suggest not using this term unless you did use it to force the model.

Response

We used air temperature, wind speed, relative humidity, incoming solar radiation and precipitation, to assess the amount of evapotranspiration as well as surface runoff.

Line 274: We changed the "… used to force …" to "… were implemented in …".

21)Comment

Line 344. Was Ks measured or assumed?

Response

Ks was estimated during model calibration.

22)Comment

Line 347. "…was used to estimate"

Response

Line 375. It was corrected.

23)Comment

Line 376. "…into the sire from adjacent farms". Replace 'farms' with 'fields'

Response

Line 404: It was replaced.

24)Comment

Line 386. Clarify "This approach" at the start of the sentence.

Response

Lines 414-415: It was added " …, using the sine function, …" to clarify "This approach, …"

25)Comment

Line 389-392. This sentence is long and hard to follow, suggest revising.

Response

Lines 417-421: The sentence is rewritten.

26)Comment

Line 421. State somewhere that these methods were used to assess model accuracy

Response

Line 454: “These methods were used to assess model accuracy” was added.

27)Comment

Table 1. Remove “Source” as a column heading if it is not used.

Response

It was removed.

28)Comment

Line 452. Suggest revising to “…the near absence of flow”

Response

Lines 489-490: It was revised.

29)Comment

Line 462-463. Suggest revising to” Although peak tile drainage flow was not always…”

Response

Line 499-500: It was rewritten as it was suggested.

30)Comment

Line 474. Saturated soil storage and water table depth appear to be used interchangeably, which causes some confusion. Suggest sticking with one term or the other if you are implying the same physical state or clarifying the use of both terms.

Response

To prevent confusions, in Figure 5, and the vertical axis title was changed to SS. Also, in line 512 we removed “…observed water table …”.

31)Comment

Figure 5. Same comment as above. Y-axis lists ‘SSS’ and ‘WT’- suggest sticking with one or the other as per above comment.

Response

Vertical axis title in Figure 5 was changed to saturated storage (SS).

32)Comment

Lines 506-509. Provide more specifics about the “systematic issues” and provide some ideas on why the surface flow is not predicted well and how you plant to improve it.

Response

As presented in lines 536 -540, one of the systematic issues in the surface flow simulation in CRHM is that CRHM adds and removes water instantaneously to depressional storage and so was not able to calculate the lag-time related to filling up the ponded areas and outflow from the ponds which is proportional to the water level within ponded areas. By adding those storage related lag-times and route to surface runoff the simulated surface flows were closer to measured.

33)Comment

Lines 513-526. Suggest providing additional context here. What are these collective differences suggesting about the overall model?

Response

Lines 551-553 and 567-570: Some additional context was added and some sentences about the overall performance of the model were added in section 3.4.

34)Comment

Figure 6. Might be helpful to present the R2 values for relationships.

Response

To be consistent with Table 2 we added NSE, RMSE, Bias, PBias and RSR to the cumulative surface and total flows in Figure 6.

35)Comment

Line 545. Change “have” to ‘had’ a strong influence”

Response

Line 588: It was changed to “had”.

36)Comment

Line 546. “…that flowed into tiles.

Response

Line 590: It was revised.

37)Comment

Table 2. Revise for consistent significant digits across the table

Response

Table has been revised to have consistent two digits after the decimal point.

38)Comment

Line 591. “ore” should be ‘more’

Response

Line 636: It was corrected.

39)Comment

Line 598. Again, suggest sticking with either water table (WT) or saturated soil storage (SSS) but not using them interchangeably to avoid unnecessary confusion.

Response

Lines 637-638. We have corrected this to SS. Also, in Figure 8 the water Table (WT) observations were presented we deleted “water table” and now presented this as “saturated storage” because, water table observations and the simulated soil saturated storage (SS) are equivalent. In Figure 8 vertical and horizontal axis and the figure caption also were revised.

40)Comment

Figure 9 caption. Same comment as above- use either SSS or WT but not both. Also, should it be water table depth or just water table?

Response

We now show values as Saturated Storage in Figure 9.

41)Comment

Line 612-624. Can you use the relationship you found between capillary fringe and drainable water to improve observed vs. predicted flows? While this might be too much to add to your results, discussing how one would use these data to improve CRHM-TD module seems like an important area to discuss.

Response

The relationship between capillary fringe thickness and drainable water, as well as groundwater fluctuations to tile flow, cannot be summarized in a simple relationship or equation, and to use these relationships, one should use the CRHM-TD module.

Another important point is that some of these relationships are more controlled by the existing delay in the drainage of water from the capillary zone. In our future research we will work on finding some simple approach to consider this delay in our simulations.

42)Comment

Line 627. Should 'K' be "Ks" for saturated hydraulic conductivity?

Response

Yes, it should. Also in Table 1, K had been defined as saturated hydraulic conductivity, based on the referee's suggestion, we have changed K to Ks in the whole document (i.e. in Line 674 and in Table 1).

43)Comment

Line 635. Same comment re: WT or SSS- use one or the other or explain reasoning for using both terms.

Response

Line 682 and Line 693. It was changed it to SS.

44)Comment

Line 648. Same as above.

Response

Line 696. It was changed to SS.

45)Comment

Line 666-667. Similar comment as above- can you use the new relationships to improve flow predictions? How would this process unfold if you are not able to apply it now?

Response

In developing TDM, we wanted to test and capture the effect of capillary fringe thickness, drainable water, and saturated storage fluctuations on tile flow rates. Section 2.4 of the paper is explains how these three control factors are represented in the new module, which can be easily replicated and benefit the broader modelling community. Specifically, Fig. 2 shows how the representation of the capillary fridge thickness was divided into three phases, which were implemented through "if, then" statements in the model development. Equations 1 to 4 show how tile flow was calculated, as well as the effect of soil moisture and water table.

46)Comment

Line 669-670. What about the fact that tiles are 1 m deep and soil moisture was measured at 0.5 m?

Response

Lines 714-717. Those soil moisture measurements were conducted during 2011 to 2014 and were related to other studies in this area. We just used them here as additional observations. We would ideally have wanted soil moisture observations up to the depth of tile pipe (1 m), but even the moisture content observations at the depth of 0.5 m showed that almost 90% of the gravitational soil moisture drains out within 0.5 to 2.5 h.

47)Comment

Lines 681-692. Shouldn't the role of evapotranspiration be included here?

Response

Lines 729 to 737: Two sentences were added about the role of evapotranspiration.

48)Comment

Line 721. Delete space between sentences.

Response

It was fixed.

49)Comment

Line 742. As previously mentioned, preferential flow is likely an important mechanism in your field given the texture is clay loam.

Response

Future developments can explore this but our current studies have not shown it to be substantial at this site. Please check our response to comment #17, as well.

References

Cordeiro M.R.C. Ranjan R.S. (2012) “Corn yield response to drainage and subirrigation in the Canadian Prairies” Transactions of the ASABE, 55(5), 1771-1780.

Kokulan V. (2019) “Environmental and Economic Consequences of Tile Drainage Systems in Canada” The Canadian Agri-Food Policy Institute, CAPI.

Kokulan V., Macrae M.L., Ali G.A., Lobb D.A. (2019a) “Hydroclimatic controls on runoff activation in a artificially drained, near-level vertisolic clay landscape in a Prairie climate” Hydrological Processes, 33:602-615. DOI:10.1002/hyp.13347

Shook K., Pomeroy, J. (2012) “Changing in the hydrological character of rainfall on the Canadian prairies” Hydrological Processes, 26(12), 1752-1766.

Zhao L., Gray D.M. (1999) “Estimating snowmelt infiltration into frozen soils” Hydrol. Process. 13 (12-13_, 1827-1842.