Letter to the Editor:

Dear Dr. Wickert,

We would like to thank you for your support during the review process and would like to extend our sincere gratitude to the reviewers for their time and efforts in reviewing our manuscript titled ***"Development of an under-ice river discharge forecasting system in Delft-Flood Early Warning System (Delft-FEWS) for the Chaudière River based on a coupled hydrological-hydrodynamic modelling approach***" and sharing their insightful comments leading to further improvements in the quality of our work.

We have now addressed all the comments from the two reviewers and revised our manuscript accordingly. Since the majority the reviewers' comments on our second revision of the manuscript were editorial in type, we believe that the manuscript is now ready for acceptance. Below, we provide a detailed point-by-point response to each of the comments from each reviewer highlighting the changes made in the revised manuscript as well as some other editorial changes deemed necessary by us.

Reviewer 1:

Correction 1: Line 14-16, sentence is unclear. Please clarify the intent behind "no reliable method for its [under ice river discharge] estimation has been developed TO date" (fix typo). Address how under ice rating curves either don't meet the needs of this model configuration, or how they are site specific etc. and inappropriate for use here. Other methods exist, so the statement is misleading.

Response: Thank you for your comment. The statement has been replaced by the following text:

"since ordinary rating curves developed for open water conditions do not remain applicable under ice-covered conditions. Some methods such as application of backwater correction factor on open water rating curves and ice thickness-based rating curves have been developed. However, these methods are quite subjective as they rely upon human judgement and are also influenced by day-to-day local river-ice conditions."

This is reflected in line 15-19 of the marked-up manuscript.

Correction 2: Please remove unnecessary capitalization of Recession and Graphic Interpolation on line 58.

Response: The correction has been made and is reflected in line 66 of the marked-up manuscript.

Correction 3: Turcotte and Morse (2017) is "introduced" on line 63/64, but it has already been referenced several times.

Response: Turcotte and Morse (2017) conducted a comprehensive study for identifying methods to improve under-ice discharge estimation. It provides good basis for literature review and has therefore been referred several times. The statement at line 63/64 (w.r.t previous manuscript) has been modified to the following statement, and the changes are reflected in lines 71-72.

"The study conducted by Turcotte and Morse (2017) also summarized the practices observed in Nordic regions for under-ice discharge estimation."

Correction 4: Please remove unnecessary capitalization of Neural on line 80.

Response: The correction has been made and is reflected in line 88.

Correction 5: Please clarify what is meant on line 98 by 'the simplistic approach' required by operational forecasts, resulting in the choice of HEC-RAS as a hydraulic mode. HEC RAS is the industry standard, and established. Development and study are ongoing for other models, but they are not at the same level. Clarify what is meant by the simplistic approach - it's not because HEC RAS is limited/simple, it's because this study intentionally does not model river ice processes and looks only at "river ice hydraulics under fully developed ice cover conditions".

Response: Thank you for your clarifications. We agree with your suggestion and the statement has been modified as follows:

"Therefore, operational forecasters prefer to adopt a simplified modelling approach which simulates river hydraulics under the assumption of a fully developed ice cover. This approach is practical from the operational viewpoint and is less data and computation intensive as compared to a process-based modelling."

The correction is reflected in lines 106-109 of the marked-up manuscript.

Correction 6: Line 384: Please use consistent capitalization in "River forecast Center".

Response: The correction has been made and reflected in line 463 of the marked-up manuscript.

Correction 7: Line 673, 718: Please use consistent capitalization for "Perfect forecast". Has been referred to as "Perfect Forecast" previously.

Response: Thank you for pointing out the inconsistency. This has now been rectified throughout the manuscript.

Correction 8: Please remove unnecessary capitalization of Future on line 749, and add 'the'. As in 'In the future...".

Response: The correction has been made. It is reflected in line 898 of the marked-up manuscript.

Reviewer 2:

The reviewer had suggested editorial changes in the organization of the manuscript. Most of the recommendations of the reviewer have been incorporated in the revised draft. Below is a point-by-point response to the comments made by the reviewer.

Comment 1: l. .33 – 34: Please reformulate.

Response: The sentence has been restructured and it now reads:

"The hydraulic module had an RMSE between 0.1 m to 0.5 m. The higher error in RMSE can be attributed to the uncertainty in the ice thickness estimates at one of the stations. The PBias analysis of the hydraulic module also resulted in negative values meaning that the simulated water levels were lower than the observed water levels. This confirmed that the forecasted discharges were under-estimated by the hydrologic module."

The changes are reflected in lines 35-41 of the marked-up manuscript.

Comment 2: l. 36: Do you mean a total river length of 188 km?

Response: We believe the reference is being made to line 136. Yes, we meant total river length of 188 km. The sentence has been rephrased to communicate the meaning properly. The changes are reflected in lines 156 of the marked-up manuscript.

Comment 3: l. 36 – 37: Please describe why you divide the catchment into three sub-catchments.

Response: The following explanation has been added:

"Based on the hydrometric station network, the Chaudière River basin was divided into three sub-catchments: (i) Upper Chaudière, (ii) Intermediate Chaudière, and (iii) Famine. This subdivision facilitated the representation of distinct hydrologic response units and provided the necessary boundary conditions for the hydraulic model."

The changes are reflected in lines 157 to 161 of the marked-up manuscript.

Comment 4: l. 45 – 46: Clarify the difference between the information in Ghobrial et al. (2023) and Montero et al. (2023) to which you are referring above. Is it only the river ice characteristics?

Response: Yes, information regarding the river ice characteristics of the Chaudière River can be found in Ghobrial et al. (2023). This has also been clarified in the manuscript. The change is reflected in line 172 of the marked-up manuscript.

Comment 5: l. 39 – 46: Please also describe the third sub catchment, the Famine. It is also better to start with the sub-catchments of interest.

Response: The paragraph has been reworked. The changes are reflected in lines 162 to 175.

Comment 6: l. 60f: Please refer to table 2 here.

Response: The reference has been added. The change is reflected in line 189 of the marked-up manuscript.

Comment 7: Table 1: Please add the mean river slope for the Famine sub-catchment.
Response: The mean slope information has been updated in the table. The change is reflected in Table 1.

Comment 8: Fig 1: You are mentioning in the legend only that you are developing the model on the Intermediate Chaudière only. I think you can make this clearer also in the figure, because the currently used color difference is hard to see. Also, the legend for your DEM is missing. Concerning the DEM, the elevation differences are hardly visible, you may want to use a hillshade with vertical exaggeration. Please translate your map labels whenever possible, e.g. "lac", "rivière", "Ville de Québec".

Response: The natural river is coloured blue in the map. The modelled reach is added as a thick black line to distinguish between part of the river being modelled from the unmodelled part. The DEM is not intended to be shown but rather the sub-catchments are to be shown, therefore the legend for the DEM has been removed. We have overlayed the DEM with slope and hillshade rasters to improve the appearance of the map. The base map has been changed to get English names of the places. The labels have been altered to reflect the English names of the features in the catchment. The changes are reflected in Figure 1.

Comment 9: Table 2: Please clarify the difference between the precipitation data.

Response: We have added a new column indicating the type of data for example observed data or forecast archive. A general explanation here is that in Quebec most of the meteorological stations

are operated by MELCCFP (which is the provincial authority in Quebec) and this data is distributed through the CLIMATO database. Some meteorological stations in the province are owned by Environment and Climate Change Canada (ECCC). Meteorological data from stations from both these agencies has been obtained and incorporated into the Delft-FEWS database.

Comment 10: l. 86: "is" is missing.

Response: The correction has been made. It is reflected in line 219 of the marked-up manuscript.

Comment 11: l. 90: "estimates"

Response: The correction has been made. The change is reflected in line 223 of the marked-up manuscript.

Comment 12: l. 131: "Study area and data" or you may name this section "Data", 2.1. "Study area: The Chaudière River" and 2.2. "(Available) data".

Response: The name of the section has been changed to "Watershed and data." The changed is reflected in line 151 of the marked-up manuscript.

Comment 13: l. 140 – 146: Please describe here all sub-catchments you are working on.

Response: The paragraph has been modified following suggestions in comment #5. The changes are reflected in lines 162 to 175 of the marked-up manuscript.

Comment 14: l. 215: Your methodology is not easy to follow. Please add a workflow including the major steps, models or data you are using to clarify your approach.

Response: A flow chart describing the overall approach has been added to the methodology section. The change is reflected in line 296 of the marked-up manuscript.

Comment 15: l. 216 – 225: This seems to be rather part of the introduction where you are stating the research gaps. To my understanding, this is not part of your methodology.
Response: We agree with the observation. The paragraph was made a part of the methodology to give additional context to the reader and build rationale for the methodology; however, we understand the viewpoint of the reviewer and we moved the paragraph to the introduction section of the paper. It is now placed at lines 122 to 132.

Comment 16: l. 226 – 245: Please split and make sure that you have one paragraph where you are only describing the overall approach, without comparing to the literature. The state of the art should be part of the introduction, and a comparison or evaluation of your work compared to existent literature goes into the discussion section.

Response: The methodology section has been reworked to convey simply the methodology of the approach and literature review has been removed. The changes are reflected in lines 257 to 303 of the marked-up manuscript.

Comment 17: l. 233: Do you mean Environment and Climate Change Canada?

Response: Yes. The reference to ECCC has been updated in the text and the change is reflected in line 275 of the marked-up manuscript.

Comment 18: l. 245 (section 3.1.): Please clearly state if you are using only their data or performing any forecasts yourself. In the first case, you may even add it to the previous section detailing the data availability.

Response: We have coded the configuration to import the ECCC REPS into the Delft-FEWS and we use it as is. We don't issue any meteorological forecast ourselves. The meteorological forecasts which have been issued in the past by the ECCC's REPS are archived into the Canadian Surface Prediction Archive (CaSPAr). We have retrieved REPS predictions from 2019 through CaSPAr and imported them into Delft-FEWS. This is mentioned in the Data section in Table 2. For further clarity we have added the line:

"retrieved from the Canadian Surface Prediction Archive (CaSPAr)."

The change is reflected in line 317-318 of the marked-up manuscript.

Comment 19: Fig 3: Please give more information in the legend of this figure, similar to your response to my previous comment. Moreover, your arrangement of tiny catchments and much not necessarily important space around them makes this figure still hard to read.

Response: The image is a display of the REPS forecasts as shown in the Spatial Data Display window of Delft-FEWS. We have little control on the image configuration, but we added a label to the legend and tried with a new "Zoom" to obtain a new image that somewhat addresses the comment. The changed is reflected in line 320-321 of the marked-up manuscript.

Comment 20: l. 261 – 286: Please split this section into paragraphs of standard length (~100 to 200 words) and clarify.

Response: The section has been reworked incorporating the changes suggested. The changes are reflected in lines 323 to 393.

Comment 21: Please describe your data in the previous section on available data to avoid confusion and improve readability here.

Response: The lines have been moved to the Data section of the paper to improve readability and flow. The changes are reflected in lines 342-346 (removal of text) and lines 245 to 249 (added text) of the marked-up manuscript.

Comment 22: l. 274: Please clarify why you choose a 3h timestep.

Response: a short justification has been added. The change is reflected in lines 346 to 350 of the marked-up manuscript.

Comment 23: l. 278 - 280: How are the procedures to average daily discharge series to 3h discharge series used here and in 2.2 different? Please clarify this paragraph.

Response: In section 2.2 the procedure for decimating the daily discharge timeseries into a fine resolution timeseries was described. It consisted of applying the daily backwater correction factor on the uncorrected instantaneous discharge timeseries that was available to us. However, we didn't have access to the uncorrected instantaneous discharge timeseries for data from 2008 to 2016. So we used linear interpolation to decimate the daily discharge data to 3h discharge data. This is how the two methods differ. The linearly interpolated data was used only for the calibration and validation of the hydrological modelling framework HOOPLA. The paragraph has been modified for clarity. The changes are reflected in lines 350 to 358 of the marked-up manuscript.

Comment 24: l. 294 -307 and figures 4 & 5: The evaluation of your model should be part of your results, instead of methodology section. Please rearrange and only describe concisely your methodology here.

Response: The changes have been made, and the results have been moved to the Results section of the paper. The changes reflected in lines 369 to 393 (text removed) and lines 669 to 694 (text added).

Comment 25: l. 366 – 376: Please verify this section again and include the information in their corresponding sections, i.e. the data or results section.

Response: This section describes the hydraulic model. The data used for calibration and validation along with results is not a part of the current study. This is a part of another study and has been properly referenced (Ladouceur et al., 2023).

Comment 26: l. 377 – section 3.4.: This section is overly long, please be concise and/or split into subsections.

Response: The section has been reworked and split from methodology. We have now added a section dedicated to FEWS development. The changes are reflected in line 456.

Comment 27: l. 378 – 409: As far as I understand, you are only describing the Delft-FEWS framework here, without any direct link to your methodology and project. Please be more concise here and refer, when necessary, to existent literature and include only information relevant for your approach.

Response: FEWS introduction has been trimmed down. The changes are reflected in lines 471 to 491.

Comment 28: l. 410 – 413 & figure 7: This seems to be the general methodology, not part of Delft-FEWS. If I understand this right, please move it to the beginning of the methods section, where such a general workflow is missing.

Response: The flowchart is a representation of the workflows we have coded/configured inside FEWS as part of the study. Since these workflows are a part of FEWS, the flowchart is kept in this section and a general flow chart explaining the overall methodology has been added in the Methodology section of the paper.

Comment 29: l. 454 – 463 & figure 9: This seems to me again too much specific information in the main part of the article on Delft-FEWS. I do not see how the screenshot is conveying relevant information about your approach to the reader. If you do want to specify your work on Delft-FEWs, I recommend including them in the supplementary materials.

Response: In the new version of the manuscript the information is now under a new section dedicated to Delft-FEWS so we feel it is appropriate system information that completes the readers understanding of the system's configuration and capabilities. As for the figure showing the configured interface inside Delft-FEWS, we feel it is very important since it shows the configuration of the system that we have developed/coded based on the specific needs of such an operational system. This interface is not a standard window in FEWS, but we designed it by coding it into the system. Reader who will be interested in getting FEWS-related insights would want to see how the system looks like and how the interface has been configured for operational use.

Comment 30: L467: Who has developed this system? In this study or a previous study? Due to the mixing of literature, description of software and your work, your contribution is hard to identify.

Response: The team that has authored this paper has developed the system. The previous publication referred to as Montero et al., 2023 was a conference presentation/paper which described the progress in the development of a River Ice Forecasting Testbed. The current paper describes the complete work and the system performance. The main differences from the progress to completion include integration of data assimilation capabilities to the system and a pre-routing routine in the hydraulic module of the system.

Comment 31: l. 485 – 496: Similarly, it does not seem to me that these sections belong here as they are, as they are only referring to the hydrological model.

Throughout this methodology section, you are referring to the numerical processing load. It may be useful to regroup these considerations in a separate paragraph.

Response: The paragraph has been moved to the methodology section and placed under the sub-section describing HOOPLA. The change is reflected in lines 572-580 (text removed) and lines 333-341 of the marked-up manuscript.

Comment 32: l. 547 – 548: Please separate clearly the methodology and results section. I don't think that this is the right place to explain the forecasting procedure.

Response: The operational procedure for FEWS forecasting has been moved from the Results section to the FEWS dedicated section (i.e. section 4) of the paper. The change is reflected in lines 695 to 725 (text removed) to 584 to 617 (text added) in the marked-up manuscript.

Comment 33: l. 548 -560: Please be concise on the data availability and the used data.

Response: We assume you refer to ice thickness data that has been used. We acknowledge the concern. This detail has now been added to the data section of the paper. The change is reflected in lines 203-204 and in Table 2 of the marked-up manuscript.

Comment 34: Fig 10: These data are input data you have downloaded and processed, if I am understanding well. Therefore, I do not think that they should be included here, because they are not a result of your work.

Response: Your interpretation is correct. The meteorological data is shown graphically to present the readability of the conditions. This is indeed not a result and has hence been moved to sub-section 4.2 RIFT Operating Procedure. The change is reflected in lines 722-725 (image and caption removed) to 614 to 616 (image and caption added) of the marked-up manuscript.

Comment 35: Fig. 11: The difference between the two forecasts is difficult to see. Please improve the readability of your figure.

Response: The challenge with the figure is that the first forecast has a very high flow magnitude especially in sub-plot (a) representing Upper Chaudière sub-catchment. This make the scale very large and hence the sub-sequent forecasts which have smaller discharge are affected by the vertical axis scale. We can provide the figure for each forecast separately as supplemental to this paper, if this satisfies the concern.

Additional Changes:

Change 1: Fig 12 (which in the previous manuscript was Fig. 11) has been slightly reworked to add lines to the area bands around the mean. Also, the observed discharge for Upper Chaudière has been smoothened by averaging it over a three-hour window. The previous timeseries showed unnatural kinks.

Change 2: In Author Contribution section the full names have been replaced with initials. Changes reflected in line 910 to 914.

Change 3: In the Acknowledgments section the contribution of the two reviewers in improving the quality of the manuscript has been recognised and mentioned.

We are hopeful that these changes to the manuscript will be up to your satisfaction. We are thankful to your cooperation.

Best regards,

Kh Rahat Usman and co-authors.