Response to comments

We acknowledge and appreciate the comments provided by RC1. We find that the comments were accurate in pointing out weaknesses of the manuscript especially with respect to missing descriptions and literature review of key methodologies/outputs. We therefore kindly submit the following responses to each comment made in order to improve the document.

No	Comments from Reviewer RC1	Authors Response	Authors Changes
1	Title: The title provided is too generic. I suggest to change it focusing on the UAS technologies for surveying.	We note and agree with the comment. The study indeed relies on the results of the UAV products and RTK GNSS (i.e. low cost technologies)	We changed the title to 'EVALUATING LOW COST TOPOGRAPHIC SURVEYS FOR HYDRAULIC RATING'
2	Abstract. The abstract is too long. It should be a very brief summary of your paper.	We note the lengthiness of the abstract. We identify that we include a long methodology explanation which may not be necessary for an abstract.	Abstract was shortened. This will be achieved by excluding the elaborate methodology explanation
3.1	The introduction is too generic and doesn't focus on the main questions of the paper. Some references are missed or included only in the following sections.	We identify the shortcomings of the Introduction. Mainly through the specific exclusion of : 1. Information on the RTK GNSS equipment (Accuracy, cost, method) 2. The gridding or merging approach of the bathymetry 3. The doming effect and lens distortion (brown Conrady, Fixed camera parameter FCP etc.) 4. The influence/importance of the slope	We have significantly altered the introduction to add all the important missing information. We changed the introduction such that the novel attributes of the manuscript as well as the objectives are fully described.
3.2	Some main research questions (e.g. the impact of lens distortion on geometry accuracy) are introduced only in the final sections.	This is a critical missing component.	We added the missing information earlier on in the manuscript. **E.g**. the impact of lens distortion accuracy the observation of slope and the merging of dry and wet river profile
3.3	Authors should include a complete overview of previous research on this topic (at line 108-111) in order to evidence the added value of their outcomes.	It is noted that there are references necessary to support the claim that **'limited studies have investigated how critical factors** (GCP number and distribution, lens distortion, slope, free and open source software**) can be adjusted to improve hydraulic modelling'**	We added all the missing reference literature on how previous researchers have not focused on 1. How factors can be adjusted to improve elevation models 2. how to combine the wet and dry bathymetry
4.1	Please move the research questions at the end of section 1 "Introduction".	Noted	The research questions were be moved from section 2 to the end of section 1 as advised.
4.2	I suggest to create a new section for "Study site". To this regard, an overview of the morphological and hydraulic characteristics of the river reach can be useful.	To give the reader some insight into the environment within which the study is conducted, we agree with the comment and add a 'study site' section to describe the river characteristics	We described the '**Morphological and hydraulic characteristics of the river** reach' under the study site section
4.3	Respect to the third research question (line 128), please clarify that the objectives are referred to the error estimation of some variables useful for the indirect estimation of the	The objective was indeed misleading to reader as it may have been misconstrued as estimation of discharge rather than an estimation of proxy	Objective was changed to be more specific 'What impact does utilising elevation models, reconstructed based on

	discharge (hydraulic conveyance and slope).	variables such a conveyance and slope	different GCP numbers have on conveyance and hydraulic slope'
5	Sub-section 2.2.1. Line 145. All the configurations used for the study it should be specified at this point.	The various configurations were indeed missing. Especially those to do with the GCP numbers and distributions	We added a paragraph which describes the configurations for the various experiments. Particularly the GCP distribution and density. To aid with configuration visualization, we added an image of the flight pattern which was used to collect the images.
6	Section 2.2.4. Line 185: The information relative to computer performance can be useful if a comparison between the two software on computation time is achieved.	To be able to authoritatively compare software it is indeed noted that all computer hardware variables need to be mentioned.	We added more information on the computer performance. In addition we added a reference to the minimum hardware requirements according to the software developers
7	Section 2.3.2. Line 230. I suggest to specify how the GCP points are spatially distributed along the river pattern especially respect to the vertical variability.	Seeing as literature suggests that GCP distribution is critical to achieve good accuracy, it is noted that it would be useful to explain the distribution methodology used.	We describe how the GCP are distributes (E.g. the 2-1-2 or checkerboard formation) and also outline how the maximum and minimum elevations were taken into consideration in order to not only have a representative horizontal distribution, but a vertical distribution as well.
8	Sub-section 3.2: The configuration Brown-Conrady is not described in the main text.	Brown Conrady is linked to one of the key factors which determine if photogrammetric geometry will be accurate. Its omission in the main text is an error	We added a literature review on the Brown Conrady as well as other calibration models to the main text (Introduction). We will also describe some of the configuration which can deal with the doming effect such as FCP in the main text.
9	Section 3. A separate discussion section should be added in the main structure of the manuscript. This section should include a comparison with other research studies and should be extended to other aspect that play a role in this analysis, i.e. the flight mission planning and the camera settings.	There are indeed some factors which are not looked at in this topic but, however need to be mentioned.	We added a section which takes a closer look at how other studies have assessed the impact of other factors which are not the subject of this particular manuscript such as flight mission planning, camera setting , flight height, speed, direction, light conditions etc.
10	Section 3.3. Line 325. It is not clear how the slope is calculated based on photogrammetry products.	An explanation of how slope is derived is missing.	We added a description of the method of slope calculation. This will include a brief explanation of a python module called 'rasterio' which is able to interpret raster images, and therefore extract elevation values (Z) which correspond to the RTK line (the 'true') slope coordinates (X,Y)
11	Section 3.3. Line 336. This step require more details for a better explanation of the procedure.	A more detailed explanation is necessary to aid the reader.	We break down the procedure into the different processes (extraction, merging, volumising). We then describe each process individually. E.g. the extraction entails overlaying the wet bathymetry on the DEM and cutting out the shape using a special tool in cloud compare'
12	Conclusion and recommendations. Line 377. Please clarify this point in the section "Methods and material": the number of points used for reconstructions and those for validation.	A description of the exact number of points used was indeed missing. This is in terms of the GCP vs check-points	We will add a description of all the various GCP configurations which were used to 2.2.1 'Flight Plan'
13	Figures: - Please improve the overall quality of the figures.	Noted	We either adjusted or redid some of the figures in terms of the actual image quality, labelling and caption

13.1	Generally, captions are not very descriptive. Please modify accordingly.	Noted	We adjusted all captions such that they fully describe what can be seen in each image
13.2	Some figures are not described in the main text (e.g. Figure 11, Figure 5b).	Noted	We made sure that all all images are fully described. Figure 6 in particular has been explained. A step by step description will be added to section 2.2.4 'processing dry and wet bathymetry'
13.3	In some figure, useful information is missing: the name of cross-sections (figure 7), the measure units (Figure 11), flow direction.	Noted	We will adjust these and other images appropriately

We acknowledge and appreciate the comments made by RC2. We are greatly encouraged to hear that the reviewer finds the data collected potentially interesting and of practical use to water managers in developing countries. As advised by RC2, we acknowledge the need to reorganise the paper to focus more on the novel attributes such as the 'gridding' approach, low-cost GNSS based bathymetry, RTK line. We therefore submit the following point by point responses to the reviewer comments.

	Comments from Reviewers RC2	**Authors Response**	**Authors Changes**
1	clarify in the abstract that GNSS data are used to characterize the subaqueous bathymetry, and UAVs are only used to map the dry surfaces.	The manuscript indeed misses out on the opportunity to describe much more about the low-cost GNSS. Which we believe could be revolutionary in terms of access to accurate measurements for researchers with smaller budgets.	We adjusted the abstract to clarify that the GNSS is in fact the key tool for the wet bathymetry reconstruction. We also added a description of the system and its costs to the main text.
2	The description of the UAV flight path is not clear. Was the UAV flown in one direction back and forth ("lawnmower" style) or in two direction back and forth ("checkerboard" style)?	Given that the flight path is important as mechanism that can be manipulated to reduce the doming effect, it is noted that the specific flight method must be clarified.	We added a description of the flight path as well as a figure to aid with visualisation.
3	The flowchart in Fig 5 needs to be described better. For instance, what is "MVS"?	The flow-chart which describes the SfM processing of the dry bathymetry was indeed not described. Including terms such as Multi view Stereo (MVS)	We redid the image to include fully described terms rather than acronyms and we detail a step by step description of the flowchart in section 2.2.4 'processing dry and wet bathymetry'
4	clarify how the slope was extracted – was a plane fit to the DEM? Is the slope computed from the average of dry points?	An explanation of how slope is derived is missing. NB* The slope will be compare to the slope of the RTK line (collected using the rolling cart)	We added a description of the method of slope calculation. This includes a brief explanation of a python module called 'rasterio' which is able to interpret raster images, and therefore extract elevation values (Z) which correspond to the RTK line (the 'true') slope coordinates (X,Y).
5	I believe this is the first mention of "Fixed Camera Parameter". This needs to be described earlier and in more detail. The method is partly described later (line 345) but that is out of place.	The term FCP is indeed misplaced and is supposed to be described in the introduction in-line with methods which can potentially decrease the impact of lens distortion (doming)	We added a description of FCP to the main text, including references and why it is potentially useful.

6	Figure 13 makes it appear there is a lateral slope of the water surface. Was there? Can we be sure the RTK system is working properly?	We had the opportunity to do simple pre-experimental tests on the accuracy of the RTK system and its accuracy was working. There was no lateral slope of the water surface. However the extreme left bank of the river was inaccessible due to overgrown vegetation. This implies that a small section which would equalise the water levels on the left and right bank is missing.	We provided an explanation for the apparent lateral slope. Unfortunately selecting a location which would satisfy this condition and many other conditions such as a straight reach, accessible flood plain, etc. was not straightforward
7	Figures B4 and B5 do not have legends.	Noted	We added legends to both figure sets.