On behalf of the authors we would like thank both anonymous reviewers for their constructive comments regarding our manuscript. We are certain that these comments greatly improve our manuscript and they will be incorporated in a revised version of the manuscript.

In the following section we will reply to all comments of both reviewers denoted with R1 (i.e. reviewer comment 1) and A1 (i.e. author response 1), respectively. As major parts of the manuscript including introduction, discussion, conclusion and abstract are modified based on the comments and suggestions of reviewer 1 and 2, we added the entire modified manuscript at the end of this response.

Reviewer #1:

R1: Page 3, section 1, from line 30: I suggest to include also "Montgomery, D.R., Collins, B.D., Buffington, J.M., Abbe, T.B., 2003. Geomorphic effects of wood in rivers. In: Gregory, S.V., Boyer, K.L., Gurnell, A.M. (Eds.), The Ecology and Management of Wood in World Rivers Bethesda (MD) American Fisheries Society, pp. 21–47.".

A1: We acknowledge the literature suggestion. After careful studying the reference suggested, it was added among others to the introduction chapter of the manuscript.

R2: Page 4, section 1: I should advice the authors to demonstrate and stress why this paper is very important.

A2: Based on the comment of anonymous reviewer 2, we modified large parts of the introduction, clarifying objectives and the relevance of our study.

R3: I suggest to the authors to change the title of the chapter with "geological setting" including only the information about the catchment. The information about the study reach should be move into a new sub-chapter (e.g. study site) in "material and methods" chapter.

A3: We disagree. In our opinion the description of the study reach should receive its own chapter and does not fit to the chapter "Methods" or "Material and methods". The name "Material and methods" suggests a description of the methods applied and materials used, which we find are the topographic datasets as well as the discharge data from field experiments but not the description of the nature of the study reach. In addition, we find that information about the geological setting of the entire catchment should and are already given in chapter 2 but should not receive its own chapter, because the description of the catchment geological setting is of minor relevance for the hydrodynamic simulation of the 282 m long study reach. However, to clarify the content of chapter 2, we changed the name from "Study area" to "Study reach".

R4: Page 4, section 2, between lines 15-25: If possible, the authors should provide the grain size distribution of the study reach.

A4: Detailed grain size analyses were not performed and thus, information about grain size distributions in the study reach cannot be provided.

R5: Page 4, section 2, line 13: Please, you should add the longitude and latitude of the catchment.

A5: We added the longitude and latitude of the catchment's centre (reference system WGS84) to the text.

R6: I suggest to change the title of the chapter with "material and methods".

A6: We changed the title of chapter 3 to "Material and methods".

R7: Page 5, section 3.1, between lines 15-20: Please, remove the word "accurately" or give any quantity information about the accuracy.

A7: We removed the word "accurately".

R8: Page 5, section 3.1, line 5: ": : :management application". Please, you should add a reference about it.

A8: We added additional references and modified the section in the following way:

Original:
"HYDRO_AS-2D was developed for practical applications in water management (Nujić, 2006) and is used in several studies simulating flow conditions in river sections (i.e. Lange et al. 2015) as well as in flood risk management applications.

Modification:
"HYDRO_AS-2D was developed for practical applications in water management (Nujić, 2006) and is used in several studies simulating flow conditions in river sections for flood risk management (i.e. Rieger and Disse, 2013) or with an ecological focus (i.e. Lange et al., 2015) and can produce a higher goodness-of-fit compared to other two-dimensional models as exemplarily shown in Lavoie and Mahdi (2017)."

R9: Page 5, section 3.1, line 17: Please, remove or give more information about the term “accurately”.

A9: See response A7.

R10: Page 6, Section 3.2, between lines 30-5: Please, could you provide some information about the orientation of the LW placed in-channel? Were they placed cross-stream or stream-wise?

A10: In the field experiments (Wenzel et al., 2014), the large wood elements were placed lengthwise in the channel. This information is already given in the original manuscript:

Original:

“The first 8 experimental runs were conducted with 9 large woody debris elements (spruce tree tops with a length ranging from 3 to 11.5 m, mean length 8.5 m), which were placed and fastened in the channel lengthwise 9 months earlier.”

R11: Page 6, section 3.2, between lines 15-20: Please, provide the type of interpolation you used.

A11: We used the implementation of the procedure based on Hutchinson (1989) in the software environment ArcGIS v10.5 for interpolating the DTM. We added this information in the following way:

Original:

“The final DTM for the model is generated from processing and combining all topographic datasets in the software environment ArcGIS v10.5 (ESRI Inc., USA).”

Modification:

“The final DTM for the model is generated from processing and combining all topographic datasets in the software environment ArcGIS v10.5 (ESRI Inc., USA) using the implementation based on the procedure described in Hutchinson (1989) for interpolation.”

R12: Page 8, section 3.4, lines 5 and 6: Please, change the unit of measure from cm to m. The authors should standardize the entire manuscript.

A12: We changed units from cm to m in the entire manuscript.

R13: Page 8, section 4.1, line 20: “very well” is not a scientific statement.

A13: We removed “very well” and modified the sentence:

Original:
“In general, the model simulates the characteristics of the observed hydrograph very well.”

Modification:
“In general, the model closely simulates the characteristics of the observed hydrograph.”

R14: Page 10, section 4.4, line 5: “very good” is not a scientific statement.

A14: We removed “very good” and modified the sentence accordingly:

Original:
“According to the classification of Moriasi et al. (2007), goodness-of-fit parameter values calculated for variant V3 as well as for all other simulation variants in this study indicate very good simulation results.”

Modification:
“According to the classification of Moriasi et al. (2007), goodness-of-fit parameter values calculated for variant V3 as well as for all other simulation variants in this study indicate simulation results of high accuracy.”

R15: Page 10, section 5.1, lines 11 and 12: “very well” and “well” are not scientific statements.

A15: We removed “very well” and “well” and modified the sentence:

Original:
“In general, the 2D hydrodynamic model mimics the flow conditions of the field experiments without LWD (variant BV) very well. Especially the time of rise, the rising limb and the flood peak are well represented, minor deviations can be observed

along the hydrograph's falling limb only due to the broader shape of the simulated hydrograph."

Modification:

"In general, the 2D hydrodynamic model closely mimics the flow conditions of the field experiments without LW (variant BV). Especially the time of rise, the rising limb and the flood peak are accurately represented, minor deviations can be observed along the hydrograph's falling limb only due to the broader shape of the simulated hydrograph."

R16: Page 11, section 5.2, line 14: "well" is not a scientific statement.

A16: We removed "well" and modified the sentence:

Original:

"Compared to the simulation result of the mean observed hydrograph of the field experiments without in-channel LWD, variants V1 and V2 produce less well fitting simulated hydrographs, which is also indicated by the slightly lower values of statistical goodness-of-fit parameters."

Modification:

"Compared to the simulation result of the mean observed hydrograph of the field experiments without in-channel LW, variants V1 and V2 produce less closely fitting simulated hydrographs, which is also indicated by the slightly lower values of statistical goodness-of-fit parameters."

R17: Page 11, section 5.2, between lines 20-25: Please provide a reference in the literature about the sentence.

A17: This sentence depicts a conclusion drawn based on the previous sentence where the reference (Shields et al., 2017) is given. For clarification we conducted the following adjustments:

Original:

"Emerged riparian vegetation can lead to an increase of Manning's n and hence, a decrease of Strickler coefficients due to increasing friction exerted on flow (Shields et al., 2017). Therefore, generally low flow depths, a largely continuous cover of dense grassy vegetation as well as a uneven microtopography due to i.e. elevated grass root wads observed in adjacent riparian areas during field experiments may have led to the necessity of increasing local roughness; especially due to the lack of such features in the model's calculation mesh."

Modification:

"Emerged rigid elements such as riparian vegetation can lead to an increase of Manning's n and hence, a decrease of Strickler coefficients due to increasing friction exerted on flow (Shields et al., 2017). Therefore, generally low flow depths, a largely continuous cover of dense grassy vegetation as well as an uneven microtopography due to i.e. elevated grass root wads observed in adjacent riparian areas during field experiments could have led to the necessity of increasing local roughness in this study; especially due to the lack of such features in the model's calculation mesh."

R18: Page 12, section 5.3, line 23: "very good" is not a scientific statement.

A18: Based on our findings, in this sentence, we draw a first conclusion and evaluate the incorporation of simplified discrete elements based on our objective results. However, we modified the sentence in the following way:

Original:

"…indicating that discrete elements are a very good starting point for an advancement of model implementation and further studies on the hydrodynamics…"

Modification:

"…indicating that discrete elements are an appropriate starting point for an advancement of model implementation and further studies on the hydrodynamics…"

R19: Page 12, section 5.3, between lines 20-25: ": : :This is in accordance with previous studies: : :". Please, provide a reference about it.

A19: This sentence is an introductory statement referring to the references given in the following two sentences. To clarify this connection, we modified the original section in the following way:

Original:

"This is in accordance with previous studies using three-dimensional hydrodynamic models (computational fluid dynamics, CFD). On the one hand, general flow patterns caused by large wood can be simulated using impermeable discrete elements, when an accurate simulation of flow near LWD objects is neglectable (Xu and Liu, 2017). On the contrary, simplifications of

LWD objects made during the integration process into the calculation mesh may cause deviations and inaccuracies (Allen and Smith, 2012)."

Modification:

"This is in accordance with previous studies using three-dimensional hydrodynamic models (computational fluid dynamics, CFD): For example, on the one hand, general flow patterns caused by large wood can be simulated using impermeable discrete elements, when an accurate simulation of flow near LW objects is neglectable (Xu and Liu, 2017). On the contrary, simplifications of LW objects made during the integration process into the calculation mesh may cause deviations and inaccuracies (Allen and Smith, 2012)."

R20: Page 13, section 6, between lines 18-20: "The effect of stable in-channel: : :" please, provide a reference about it.

A20: We nearly reformulated the entire chapter 6. The sentence was removed in that scope. See author response A21.

R21: In this chapter [conclusion] the authors are not properly writing the conclusions of the study conducted.
Several parts should be moved to a new subchapter in the discussions part. For example, on page 13, section 6, between lines 10 and 15, the authors talk about a limitation of the study. The same between lines 15 and 20. I think that you could talk about it in a new subchapter (e.g. limitations and future challenges), highlighting also the future development of the technique. Overall, in the conclusion the authors should present a concise and clear message, avoiding generalizations of the implications.

A21: We agree with the reviewer, that limitations should rather be mentioned in the discussion chapter and that the conclusion chapter should be formulated in a more precise way, focussing on the results obtained in this study. Therefore, we added a new sub-chapter (5.4 General limitations and implications for further research) to the discussion chapter and reformulated the conclusion chapter:

Original:

"**6. Conclusion**

The hydrodynamic simulations conducted in the present study show that average flood hydrographs of previously conducted field experiments without in-channel LWD can be accurately simulated in the small and high gradient study reach.

Nevertheless, minor discrepancies need to be taken into account, which can be attributed to lateral water influx between both weirs as well as a calculation mesh based terrain datasets lacking of small scale topographic features such as step-pool sequences and riparian microtopography. For this reason, high resolution topographic datasets acquired with high resolution survey techniques such as terrestrial LiDAR are required to obtain most accurate model results on such high spatio-temporal scale. In addition, in the present study calibration is solely conducted using the hydrograph at Thomson-weir 2. As point measurements of flow depth, velocity and inundation extent in the field would improve model accuracy assessments, multicriteria calibration approaches may be considered in future studies simulating the hydraulic effects of stable in-channel large wood.

The effect of stable in-channel LWD can be accurately simulated using roughness coefficients as it is often done in hydrodynamic model applications. However, differences in model quality can be detected between increasing in-channel roughness in the entire reach or in LWD affected spots only. A reach-wise decrease of Strickler coefficients and in turn, increase of Manning's n by 30 % is comparable to previous studies investing the impact of LWD on channel roughness coefficients. This reveals better simulation results than solely increasing roughness in LWD spots by 55 %, due to large woody debris elements affecting channel flow in sections beyond their own dimensions by i.e. forming downstream wake fields. Therefore, a reach-wise alteration of in-channel roughness coefficients results in the best simulation of LWD related hydraulic effects on reach scale flood hydrographs.

Most accurate simulations of LWD related impacts on flood hydrographs regarding its overall shape can be obtained using discrete large wood elements as proposed in previous studies (Smith et al. 2011). Here, a close-to-nature design of discrete elements in the calculation mesh is essential for precise model results and in order to reduce uncertainties caused by element simplification, dimensioning and positioning (Allen and Smith, 2012). A close-to-nature representation does include element or jam permeability. However, naturally occurring flow through branches, under and over large woody debris objects cannot be accounted for in depth-averaged two-dimensional hydrodynamic models. Combined with the high amount of work and time consumption required for implementing discrete elements in a calculation mesh (Lai and Bandrowski, 2014), discrete large woody debris objects may be most applicable in detailed investigations with three-dimensional models on high spatialtemporal scales, where a detailed simulation of the resulting flow conditions is required. Discrete elements in two-dimensional hydrodynamic model applications may be used in the scope of preliminary studies where minor deviations are neglectable. In contrast, altering roughness coefficients to represent stable large woody debris is less work-intensive and time-consuming. Hence, it may be applied to represent in-channel large woody debris on a larger spatio-temporal scale such as the catchment scale using one- and two-dimensional hydrodynamic models or in rainfall-runoff simulations, where minor differences are smaller than the overall model uncertainty. As the impact of large wood on reach-wise in-channel roughness coefficients depends on several factors including channel-width, water level, slope as well as LWD size, amount, orientation and position, ensemble-simulations with literature-based values of roughness increase may be used to simulate the influence of large woody debris. Here, reviews of recent advances in research on the hydraulics of LWD in fluvial systems would be highly beneficial; similar to recent reviews and meta-analyses addressing ecological implications (i.e. Roni et al., 2015), large wood dynamics (i.e. Ruiz-Villanueva et al., 2016; Kramer and Wohl, 2017), related risks for anthropogenic infrastructure (i.e. De Cicco et al., 2018) and large wood in fluvial systems in general (Wohl, 2017)."

Modification:

"**5.4 General limitations and implications for further research**

The present case study investigates the impact of large wood on the flood hydrographs under stable (fastened) conditions. This is often done in model-based impact assessments (i.e. Hafs et al. 2014, Lange et al., 2015) but does not necessarily represent reality. Large wood stability depends on several hydrological and morphological factors (see Kramer and Wohl, 2017) and may mostly occur in small streams and rivers, where large wood elements are large compared to the channel dimensions (i.e. Gurnell et al., 2002). Consequently, the validity of the results presented is limited to these hydromorphological conditions. A first assessment of potential large wood transport and hence, mobility can be evaluated with the conceptual model presented in Kramer and Wohl (2017). If wood transport can be expected or wood elements are not fastened, i.e. in the scope of a restoration measure, hydrodynamic simulations of large wood dynamics may be necessary as presented in Ruiz-Villanueva et al. (2014).

In addition, the model results are restricted to the specific set-up of boundary conditions of the field experiments in Wenzel et al. (2014). Thus, the results are valid for i.e. the amount of large wood, its volume and orientation as well as the channel morphology and hydrological conditions of the field experiments but might not be transferable without adjustment. Further simulations of the approaches presented in this study with varying boundary conditions regarding channel morphology and discharge are necessary to validate the results and further compare approaches of incorporating stable large wood in hydrodynamic models. This is also true for the increase of roughness determined during calibration and resulting in the best fit of the model. When modelling the potential impact of stable large wood as a change of in-channel roughness coefficients with different boundary conditions and without data of large wood-influenced discharge for calibration, the application of ensemble-simulations with literature-based values of large wood induced increase of roughness may be used for a first assessment. Here, estimation methods for large wood induced roughness increase in small, high-gradient streams and rivers, as previously developed by Shields and Gippel (1995) for large lowland rivers or reviews of recent advances in research on the hydraulics of LW in fluvial systems would be highly beneficial, as it is the case for recent reviews and meta-analyses addressing ecological implications (i.e. Roni et al., 2015), large wood dynamics (i.e. Ruiz-Villanueva et al., 2016a; Kramer and Wohl, 2017), related risks for anthropogenic infrastructure (i.e. De Cicco et al., 2018) and large wood in fluvial systems in general (Wohl, 2017).

Although the roughness coefficient approach presented in this study is feasible with all models which are based on the SWE, only models enabling the simulation of two- and three-dimensional flow conditions can be used for the incorporation of simplified discrete large wood elements. Here, further restrictions may apply corresponding to the model-specific discretion methods and hence, restrictions regarding the design of the underlying calculation mesh. Thus, different models available should be compared with similar boundary conditions. This also true for the design of discrete LW elements as part of the calculation mesh. In this study, only a single design of discrete large wood elements was incorporated as topographic features into the calculation mesh. Other designs may be also suitable such as discrete weirs (Keys et al., 2018) or arrays of pillars allowing water to flow through. Further research including a comparison of different designs of discrete large wood elements in 2D-simulations under equal boundary conditions could be beneficial. Furthermore, in the present study calibration is solely conducted using the hydrograph at Thomson-weir 2. As point measurements of flow depth, velocity and inundation extent in the field could improve model accuracy assessments, multi-criteria calibration approaches may be considered in future studies simulating the hydraulic effects of stable in-channel large wood.

6 Conclusion

The hydrodynamic simulations conducted in the present study show that average flood hydrographs of previously conducted field experiments without in-channel LW can be accurately simulated in the small and high-gradient study reach using HYDRO_AS-2D. Nevertheless, minor discrepancies need to be considered. The effect of stable in-channel LW was satisfactorily simulated using roughness coefficients. However, differences in model quality can be detected between increasing in-channel roughness in the entire reach or in LW affected spots only, where the latter results in a lower statistical goodness-of-fit. Visually, most accurate simulations of LW related impacts on flood hydrographs regarding its overall shape can be obtained using discrete large wood elements as proposed in previous studies (Smith et al., 2011) but comes with a temporal shift between observation and simulation due to the impermeability of the LW elements as well as a higher demand of effort and time for their incorporation into the model. Therefore, using channel roughness coefficients for simulating the impact of stable large wood elements on discharge time series suggests to be similarly accurate as the implementation of discrete elements on reach or larger (i.e. catchment) scale, where minor differences are smaller than the overall model uncertainty. Although constrained to limitations and uncertainties presented in chapter 5, the results of this study indicate that the impact of stable in-channel large wood may be simulated with a reduced amount of time and work required for model set-up and incorporation of discrete large wood elements through the use of roughness coefficients. Thus, model-based impact assessments of, for instance, stream restoration measures considering stable large wood, may become more feasible; especially on larger scale or in less critical channel-sections, where a fully resolved flow assessment with three-dimensional models is not required or practical. However, the present study is restricted to narrow boundary conditions, in turn illustrating the need of further research comparing methods of stable large wood incorporation in different models with varying model-dimensions and boundary conditions regarding channel morphology, large wood characteristics and water flow. Nevertheless, by comparing methods for simulating the impact of stable large wood on the reach scale, the present study can provide helpful information for practical applications in modelling stable large wood related effects in small, first order streams and rivers."

R22: As the author can read in the preface of the book of the First International conference of Wood in World Rivers (Gregory, S. V., K. L. Boyer, and A. M. Gurnell, editors. 2003. The ecology and management of wood in world rivers. American Fisheries Society, Symposium 37, Bethesda, Maryland), the term "debris" was first used to refer to the wood slash and debris left on the land and in the stream after timber harvest. For this reason, the term negatively connotes garbage or trash to the general public. The debate was reported also during the Third International conference of Wood in World Rivers in Padua (Italy) where the audience positive accepted to discourage further the use of the term "debris", encouraging the use of the word "wood". Thus, I would like to suggest to the authors to remove the term "debris" along the entire manuscript.

A22: We agree that the term "large wood" should be used instead of "large woody debris" due to the positive ecological functions of large wood in fluvial environments. We changed "large woody debris" and "LWD" to "large wood" and "LW", respectively, in the entire manuscript, all figures and the title.

R23: Figure 1. I suggest to change the DTM of the study reach with another one that can give more information about the nature of the reach. An aerial photo could be enough.

A23: An aerial image does not prove helpful in the study reach because of the dense canopy cover in the catchment of the Ullersdorfer Teichbächel. Instead, we added a more detailed map of the study reach including contour lines of the study reach and surrounding areas. Furthermore, photographs taken in May 2017 are included, giving a better overview of the nature of the reach:

Additional figure:

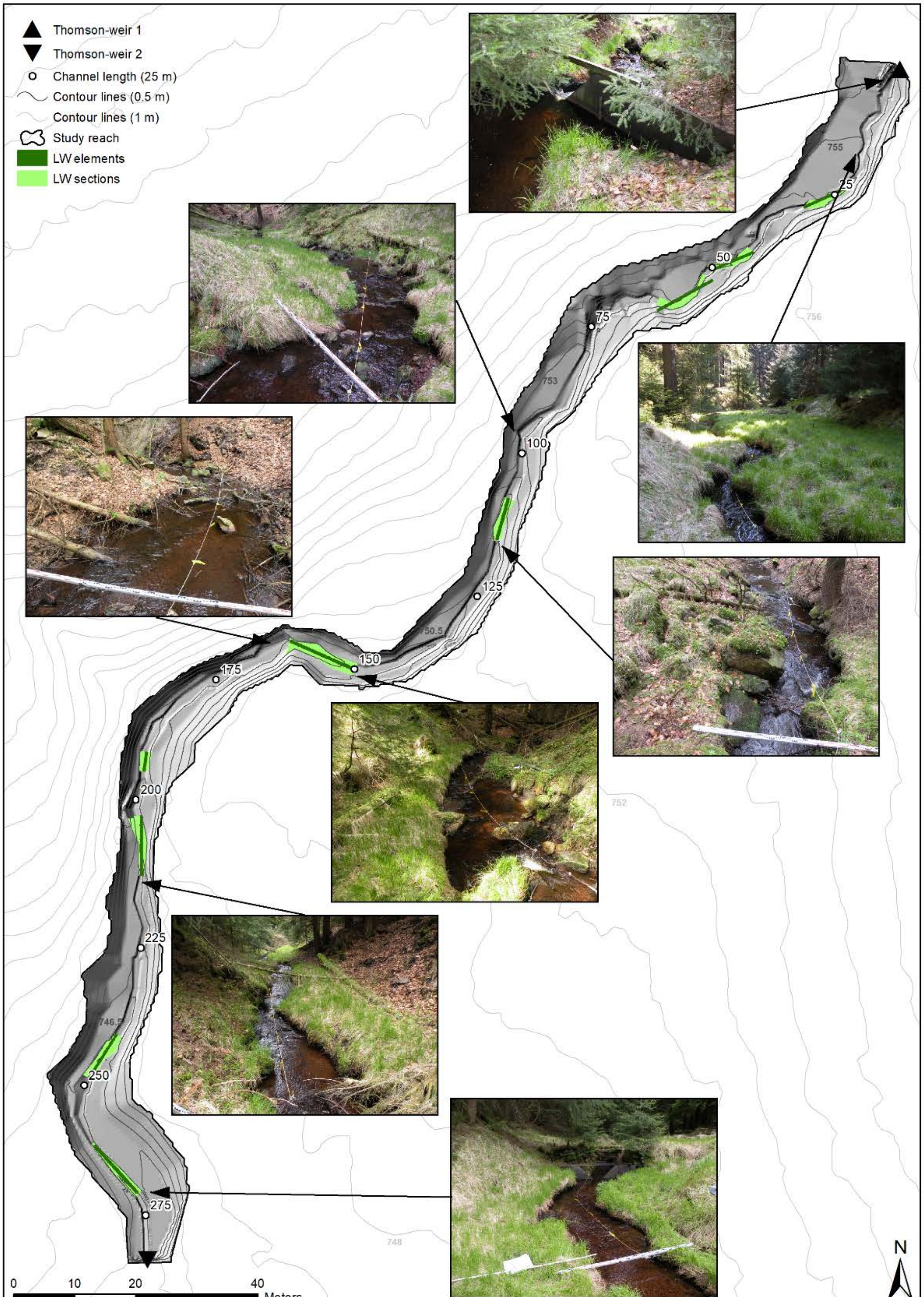

Figure 2: Detailed map of the study reach (topographic data outside reach: GeoSN, 2008). Photographs were taken in May 2017 in the direction of flow (north to south).

R24: Figure 4: I suggest to remove the titles and add the letters A, B, C, and D. Please, you should modify the text accordingly.

A24: We removed the titles of sub-plots and modified the figure description according to the letters.