Response letter to the comments of Anonymous Referee #1

Thank you very much for reviewing our article. Please find below our responses and revisions according to your comments. (Comments of Anonymous Referee #1 are formatted in Italics)

General Comments:

The paper describes the practical large-scale application of the empirical based flood damage model RAIL for the Railway infrastructure loss. These analyses are an interesting and relevant topic in the field of flood damage modelling on a special infrastructure sector.
The RAIL model is a relative simple damage model, but it follows an engineering based way and gives an estimation of a damage class for the description of the structural damage in dependence of the inundation height. The damage classes are connected with standardized repair costs for 100 m track length, which were derived in a former study.

In the paper the RAIL model was applied to the railway network of the ÖBB in the Mur River catchment. The expected annual losses were calculated on the basis of flood scenarios for three return periods.

The linkages between the individual steps of the described procedure are logical and comprehensible.

The authors are also aware of the limitations of the described procedure. It is clear that some simplifications (like equal construction heights for the substructure) must be taken for such a large investigation area also with respect to the availability of some necessary data. Finally the RAIL model itself is a simplification, because it reduces the problem (in comparison to the continuous relative damage functions of other models) to 3 values of absolute losses. Some of the uncertainties were considered in a limited range regarding the heights of the substructures of the track and the cost calibration factors for damage class 2.

From the perspective of the referee are some comments necessary.

Specific comment 1:

The first one refers the relatively low number of damage classes (in comparison to some damage models for other sectors). The increase of the values of these standard repair costs (which were derived in a former study) between the three damage classes is relative strong. So a slight increase of the water level can cause a relative strong (certainly unrealistic) jump in the expected losses for the track section if the threshold to the next higher class of damage is exceeded. This could be one reason for the large differences for the expected annual losses in the different operational sections. As appropriate, this could be discussed more in detail. For a further improvement of the damage model an increase of the number of damage classes could be checked or also the definition of a flexible range of standard repair costs (in the sense of a damage function) for the individual damage classes.

Response 1:

Moran et al. (2010a) defined five damage classes for the cross-section and we initially adopted this classification when preparing the study presented in Kellermann et al. (2015). However, the (statistical) results on the basis of that classification were not satisfactory. One explanation is that the approach of Moran et al. (2010a) also considers the possibility that the track segment is fully inundated without causing structural damage. However, both from the engineering and the economic perspective, this sequence of damage grades is not optimally adjusted since only structural damage (particularly at the

substructure) will lead to the necessity of reconstructing the track segment and will cause significant economic losses. Hence, after discussing and evaluating the initial results with railway experts, we revised the classification of Moran et al. (2010a) and reduced the number of categories from five to three with the aim to focus more on structural damage to the substructure being the most important and expensive element of the standard cross-section. This approach led to a markedly increase in the statistical correlations of flood impact and structural damage.
Generally, we think that a finer classification of structural (and economic) damage is not required, since there is no significant difference between certain grades of damage to the track, e.g. minor, medium and major erosion damage to the substructure, at least from the engineering perspective. In case the substructure is (at least somehow) damaged, the train service is disrupted and the segment has to be repaired. A further point is that only little data was available to derive the damage classes and related flood intensities. When considering more damage classes a better data base would be necessary in order to get reliable results.
Indeed, from the economic perspective, the repair costs are to some extent dependent on the damage grade of the standard cross-section. We address this aspect by calibrating the cost estimation of damage class 2 (= damage to substructure is expected) on the basis of the recorded repair costs in 2006. This resulted in a derivation of a coefficient of 0.25 being added to the calculation of repair costs for damage class 2. In other words, the costs of full restoration of 100 m of a track segment´s substructure are quartered, which corresponds to the average repair costs of all (partly) damaged substructures in 2006.

The reason for the significant differences in the expected annual losses of the operational sections probably lies in the fact that the operational sections markedly differ with regard to their exposure to flooding of the Mur River.
We will add this discussion briefly in the paper.

<u>Specific comment 2:</u>
A second comment is related with calculation of the expected annual losses. The given standard repair costs refers in general to a price structure for a specified year. The calculation of an annual loss should consider the expected future increase of the repair cost. It is directly not visible in the paper, whether this has been taken into account. A short comment to this should be sufficient.

I look forward to the further progress of the model development and its application.

<u>Response 2:</u>
The price level of the structures have to be kept a t a constant level (in our case the reference year 2008). A change in the asset values would only be required if technical improvements were anticipated. Since this would however also affect the susceptibility of the structures, constant asset values/costs were used.