Dear Referee #2

Thank you for your comments and suggestions. I would like to follow your suggestion to add a short section in the discussion on the uncertainties in the input data and their effects on the outcomes.

Response to the overall comments:

- I do not agree that this method is just another way of probabilistic analysis. It is the combination of probabilistic and deterministic modeling at the large river scale which makes this method new.

- The referee states that the method is not placed in a context of policy making, however the method is meant to support policy analysis (as stated in the third requirement) . In the chapter on case study results we will add results of alternative flood risks management strategies to illustrate the use of this method for policy analysis.

- Question of the referee on interaction between dike ring areas into account → this is a strange question since we do not use the concept of dike rings. We study the whole river stretch from the border to the North Sea and the breach locations in between. It is not relevant for the method that this area has been divided in dike rings. You could say we study the interaction between dike rings, since we study the effect of upstream breaches on downstream flood probabilities. We do not take into account the possibility of water flowing from one river branch through a breach, over a floodplain and then into another river branch. This may happen at some locations in the Netherlands (dike ring 48, 42 e.g.). However, this effect is very location specific and it is not relevant for societal risk, since the delay in time is very large. It is highly unlikely that casualties will occur due to this effect.
- I will add a discussion on uncertainties and their effects on the outcomes.
- The referee refers to the VNK2 project a lot. VNK2is a very important flood risk analysisng research project in the Netherlands. On page 1642 from line 13 onwards the VNK project has been described and discussed. The VNK2 project aims to show the risks in the Netherlands in the current situation and studies those risks per dike ring. It has delivered very valuable results. It does, however, not produce large scale risk estimates, nor does it take interdependencies between dike rings into account.
- The paper focuses on the risk analysis method and not on societal flood risks, their evaluation and tolerable risks. There are other papers which go more in depth in societal risk, which I have referred to.
- The flood probability assessment is explained in chapter 3. It is possible to assess risks corresponding with actual flood probabilities, however, the method is designed to be used to assess societal risks corresponding with alternative flood protection standards. The user then provides design failure probabilities for all breach locations and the fragility curves are shifted in such a way that these probabilities are found IF no hydrodynamic interdependencies are considered (see section 3.2) If hydrodynamic interdependencies are considered, the resulting probabilities found in the calculations differ from the probabilities provided by the user. The user can thus analyse the societal flood risks corresponding with different sets of safety standards.

- The method requires fragility curves for each potential breach location. In the application in the paper fragility curves of Van der Meij were used, which have not been published. Since fragility curves are highly uncertain, a sensitivity analysis to the effect of changes in these curves on the resulting FN curves and the most dominant dike stretches was carried out. This will be added to the section on uncertainties.
- If other fragility curves are used, the FN curve shape alters slightly. However, the selection of the most dominant dike stretches, the ones which contribute most to the societal risk, is not affected. Indeed, the fragility curves will change after dike improvement. Therefore, the sensitivity analysis has been carried out to study the robustness of the results. The actual fragility curves are highly uncertain, even for the current dikes.
- The method has been used in the Deltaprogramme to assess societal flood risks. The societal risks corresponding with the current flood risk management strategies and alternative strategies (including the proposed safety standards) have been assessed. The paper focuses on the method, but one alternative may be described to illustrate the use of the method for the analysis of alternative strategies.
- References: Most references are to people outside Deltares We included references to reports and papers of the authors and to other of the institute, but they all contain critical information (e.g. on the breach growth formula used, on previous work done, on the work done for the Dutch Deltaprogramme (WV21)). Many of the papers with an author of Deltares have coauthors of other institutes. We also have important references to the English and German work done on large scale risk analysis. Furthermore, we refer to earlier work done by the consortium Delft Cluster on system behavior (hydrodynamic interdependencies) since this work formed our starting point. In Delft Cluster project, Delft Hydraulics (which is now part of Deltares) cooperated with TNO and the TUD. If you think we miss important work, please suggest references.

Detailed comments:

- L1p1: We focus on river deltas since in these deltas both river discharges and storm surges must be taken into account. We mention the word ‘river’ since the approach is applicable for the whole lowland river part of the delta: from where the river leaves the hills and the floodplain becomes wider until the area where river flows into the sea. The non-tidal part is included as well. Risk modeling for this type of areas requires both the consideration of hydrodynamic interdependencies and the joint consideration of both storm surges and river discharges.
- L2p2: With complex we mean that both storm surges and river discharges and their correlation must be taken into account. This is more complicated than when only one of the two threats must be considered and requires another approach (e.g. a more complex importance sampling strategy). Furthermore, the effect of breaches on downstream areas must be taken into account to prevent overestimation of the risk. This is not the case in narrow river valleys or in coastal areas.
- L26p1: It is generally expressed in FN curves. There are other measures (e.g. N per year), but mostly FN curves are used. I will add references (US, UK ones etc.) and mention also the N per year as measure for fatality risks (this can be derived from the FN curve).
- P1: The literature review in chapter 2 contains an elaborated list of literature both on the VNK2 project as on German, American and English methods as well as on previous work

done in the Delft Cluster project by the TUD, Delft Hydraulics and TNO together. These are the most important works. Please add suggestions if you feel someone is missing.

- P1: I think the understanding of the Dutch system is not needed in the introduction. The method itself is also applicable to other river deltas. The Dutch system is explained in the application on the Dutch system.
- P2: The second requirement is not related to water levels only. It requires that the spatial interaction between locations is taken into account in the risk analysis. Due to a breach upstream, water levels will go down downstream which may affect the probability of failure and thus the flood risk. Maybe the term 'hydrodynamic interdependency ' is misleading. However, we study the effect on flood probabilities and risk, as is stated in the next sentence.
- The relation with VNK2 is explained in chapter 2. In VNK2 the probability of flooding of each dike ring is studied independently from the failure probability of other dike rings. The aim of VNK2 is to give risk estimates per dike ring, and not to give a regional risk indication. References are made in chapter 2.
- Maximum limit of a flood: I am not sure if I understand your question precisely.. There is no fixed upper limit of a flooding. The probability of extreme discharges and storm surges is very small to zero (the official discharge probability distribution is used). The number of breaches is limited by the volume of water in the river.
- L26P2: Please rephrase. Remark is unclear to me.
- L3p3: We looked in literature. The existing methods did not comply with the criteria. This is explained in chapter 2. I will add a reference to chapter 2 here."As explained in chapter two, we did not find a method….."
- P3: We did an elaborated international literature review in chapter 2. We will add a reference to this.
- P1642|13 → we study the effect on flood probabilities. It is even mentioned in the previous sentence. Maybe the term 'hydrodynamic interaction' is misleading?
- P1642|13. On page 1641 we discuss the VNK2 method and explain that it aims to get risk estimates per dike ring. The method of Beckers and De Bruijn on page 1642 line 13 is also probabilistic, but aims to assess societal flood fatality risks in the Netherlands, by adding correlations between dike rings. The work of Beckers and De Bruijn (2011) is older than VNK2, contains much less detail, but analyses risks in the Netherlands and not per dike ring. In line 23 and so on, the expert judgement is mentioned as a weak point. The correlations were assessed by looking at the first VNK2 results. The referee seems to be worried that VNK2 gets too little attention. We feel that the VNK2 project is a very interesting and relevant project which determines the current flood risks in great detail and that the method we discuss here is not a competitor to VNK2 in any way. It is something completely different. It works with much less detailed data, but on a larger scale, it enables the risk analysis of the whole Rhine-Meuse delta and the analysis of alternative flood risk management strategies. VNK2 does not aim to analyse what happens per event or what may happen in the Netherlands.
- P1642|17: A dike ring flood scenario is a scenario in which one or more dike rings become flooded. If there would be only three dike rings A, B and C, then the complete scenario list would consist of 7 scenario's:
    - A becomes flooded, and B & C remain dry

- B becomes flooded, and A & C remain dry
- C becomes flooded, and A & B remain dry.
- A & B become flooded, C remains dry
- A & C become flooded, B remains dry
- B & C become flooded, A remains dry
- A, B and C become flooded.

As explained for each dike ring average probabilities and consequences were used.

- 1642|24 → these comments on the method of Beckers & De Bruijn are unclear to me The fact that VNK2 provides flood probabilities does not seem relevant for this line.
- Chapter 2 does not discuss flood consequences. It discusses the effects of breaches on flood hazards and flood probabilities downstream and how this effect can be taken into account in flood risks. Different methods used to do this are discussed. This review is international. The most important methods from the UK, Germany and past methods developed in the Netherlands are discussed. If the referee misses literature, please suggest a reference.
- P1646L20: The breach locations have been taken from the VNK2 project (in 2009!) in WV21. They are based on the change in consequences: Going along the flood embankment, a new potential breach location was defined every time when flood impacts changed significantly. This procedure is explained in Kok et al. (Kok & Van der doef, 2008). (Leidraad Leidraad
- Overstromingsberekeningen voor VNK2). I will add a sentence and reference to explain this.
- P1646L20: Candidate safety levels → We mean 'alternative flood risk management strategies of alternative potential future flood protection standards'. Phrasing will be changed.
- P1647L5: The VNK2 project does not give alternative flood protection standards. The user can define those.
- Formula 1: relates to the annual maximum discharges. See line 17. I will start a new section in line 22after "lith" to make clear thar the text on daily discharges does not link back to formula 1.
- P1651: Van der Meij (2012) has not been published. The fragility curves are highly uncertain and there are different expert opinions on how they should look like for the current defenses and for future defenses which correspond to future design criteria. We did a sensitivity analysis for the fragility curves to see the impact of the shape of the curves on the FN curve and on the identification of the most dominant embankment stretches. We will add a brief discussion in the new section on uncertainties and their effects. The results of the application depend on the Van der Meij curves. However, happily they are not too sensitive for those fragility curve shapes. The method does not change I other fragility curves are used (of course).
- Chapter 4: happily, the probability of more than 8000 fatalities is very small (about 10^{-6}). It is shown in figure 4 in the paper (after the references).
- Reference to Klijn 2013 will be added.
- Recommendation 1 → will be added in the new section on uncertainties. Recommendation will be deleted.