Answers by the authors on the referee report of reviewer #1

Date: 08/05/2017

We took the original text of the review and divided it up into smaller pieces, which we answered. The original text by reviewer #1 is presented in blue, italic text, while our answers are numbered and in black.

The paper provides a coherent narrative and is clearly within the scope of NHESS. It also provides a scientific background to how engineers can systematically explore a multi-dimensional space for optimal solutions using a method unknown to many. As such it is publishable.

My review is based on my background knowledge which is more related to the traditional cost-benefit analyses in relation to risk-based design. So please bear with me if there are things I have misunderstood. On the other hand I have done exactly the same as the authors using traditional economic tools in relation to risk-based design.
I think the paper should be rewritten to improve clarity. Therefore I only have overall comments.

The paper, and in particular the Introduction section, is not very well written for the reader not already familiar with the thinking of the authors. Assumptions about prior knowledge on Dutch design criteria are very high, previous work is not introduced as more than a reference (sometimes even to studies in Dutch).

1. Thank you for this comment. We will expand the introduction to include a better introduction of relevant Dutch methods and design criteria.

The authors seem to use the term risk to characterize probabilities and economic loss interchangeably. Please define and use a clear notation. This could be done in relation to Equation 1 which in poorly defined. The problem is encapsulated in the sentence on page 2, line 17.

2. Thank you for this comment. We make the use of risk/probabilities/economic loss consistent and clear.

The authors rightly state (e.g. page 3 line 5) that the major work in relation to risk-based design is calculation of the residual risk (in monetary terms) by a complex procedure involving complex hydrological and hydraulic calculations and subsequent calculation of loss of vulnerable assets. However, I cannot see how calculation of the edges as outlined on e.g. page 4 line 5 can be done without such calculations. Indeed this is also stated on page 7, line 5. So I see a reduction in the required number of calculations in comparison to LP, but at least as computationally demanding than traditional Cost- Benefit Analyses. It is not difficult to set up the mathematical framework for optimization within economics that can identify economically optimal solutions if the risk can be formulated in a simple equation such as the authors do in their examples (e.g. Eq 3).

3. Thank you for this comment. We tried to answer it in three parts:
    - Edge calculations: It is correct that each edge is associated with a potential risk calculation. The reduction in number of calculations is indeed compared to I(L)P.
    - Traditional C/B analyses: we assume that by traditional C/B analyses, the reviewer refers to marginal C/B analyses (i.e. those that optimise flood defences separately and independently of hydrodynamic interactions in a larger system of flood defences). We will further clarify that our proposed method of looking at the whole flood defence system makes sense if hydrodynamic interactions are expected to lead to significantly different flood risk estimates. If the flood risk estimates are approximately the same with and without hydrodynamic

interactions, the economic optimisation might be done just as well (and possibly more efficiently) by looking at each flood defence independently.

- Simple equations: We purposefully chose these simple equations in order to focus on the approach and not on the examples. However, these simple equations should not be seen as representative of the risk calculations we have in mind. In follow-up research, we have a more complex case study in which hydrodynamic interactions are explicitly modelled. However, if we were to include this (or a similar) case study in this paper it would need to have either a lengthy description (muddying the focus of the paper) or a reference to future (unpublished) work which would make the case hard to reproduce. Nevertheless, we can (and will) add a description that these equations are simplified for the purpose of this paper, and can be replaced by (for example) hydrodynamic simulations in a Monte Carlo setting.

We will make these points clearer in the paper.

I would prefer if the extension involving several dikes heights to be optimized simultaneously were introduced using multiple dimensions. Since the paper only discusses two dimensions it should be straight forward also to show graphically. It will make comparison to marginal economic studies on efficiency of alternative measures quite apparent. Still, the visualization and structured approach to identify optimal trajectories makes the approach valuable.

4. Thank you for this comment. We interpreted this comment as that we need to explicitly show and describe in that the approach is applicable to more than two lines of defence. We will alter the examples section accordingly.