Long term investment scenarios and an opportunity to collaborate

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Abstract. In December 2014 the Environment Agency published Long Term Investment Scenarios (LTIS) for flood and coastal erosion risk management in England. It sets out the future costs and benefits of managing flood and coastal erosion risk in England in a range of different scenarios. Its major achievement in long-term risk-based resource allocation is to incorporate a rigorous national economic optimisation based on an aggregation of 3,000 flood defence systems covering the entirety of England's floodplain. The analysis is based on the Environment Agency's national assessment of flood risk from rivers and the sea, along with the risk of properties flooding from surface water. The risk information informs an innovative economic model to assess optimal levels of investment both in maintaining and improving the defence infrastructure, and is combined with a high level appraisal of investment in broader risk management activities (such as flood incident management). The headline results describe optimal investment profiles in the short and long term, and compare these with planned investment levels by government and external contributors. The potential to reduce flood risk in the long term is described in the context of the efficiencies required to reduce and hold down costs, the benefits of maintaining control over development in the floodplain, and the effects of climate change. There are constraints in the economic optimisation approach, as well as in the broader, inclusive overview of risk management activities, and the Environment Agency is now seeking a more open, collaborative approach – working with industry and academic partners – to develop LTIS and strengthen it further as robust, independent, world-leading evidence.

1 What are the future costs and benefits of managing flood and coastal erosion risk in England?

In December 2014 the Environment Agency published Long Term Investment Scenarios (LTIS) for flood and coastal erosion risk management in England [1]. It is an economic assessment of future flood and coastal erosion risk management in the period 2015 to 2065. It sets out the future costs and benefits of managing flood and coastal erosion risk in England in a range of different scenarios, to provide a guide to planning future investment.

LTIS estimates the optimal level of investment in flood and coastal erosion risk management, describing the annual average investment that would be needed to fund all work where benefits exceed costs. This optimal level of investment has been applied to a range of different scenarios to understand the potential to reduce flood risk in the long term in the context of (a) the efficiencies required to reduce and hold down costs, (b) the benefits of maintaining control over development in the floodplain, and (c) the effects of climate change. The purpose of this paper is not to duplicate the report, but to outline the strengths and limitations of the work to date and suggest a collaborative approach to addressing them.

2 Method of analysis

The approach taken by the LTIS analysis is to start with present day risk, based on the national flood risk assessment (NaFRA) and equivalent surface water mapping, and model changes in risk into the future. This is done by offsetting factors that increase risk (asset deterioration, climate change and development on the floodplain) with actions that reduce risk (building and maintaining defence assets, forecasting and warning, development control and incident response). Benefits of different levels of investment over the study period were identified to pinpoint the investment 'optimum'. This was then used as a baseline to test the consequences of different scenarios for climate change, development on the floodplain and future costs.

2.1 Optimising investment

Investment is optimised by assessing and adding investments in 'merit order', so those that bring the most benefit in relation to costs are added first. Returns will

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then gradually diminish as the next most beneficial investments are added until the annual average optimum level is reached. The national assessment is built up by aggregating modelling calculations carried out at a flood risk management 'system' (FRMS) level, where a system is defined as a collection of assets that protects a discrete area of a river catchment or the coast.

The economic principles underpinning the analysis are explained in more detail in Appendix B of the report [1]. In short, the economic optimum is a concept that describes the best outcome per pound spent. To establish the annual average optimum investment level, LTIS maximises net present value (NPV), where NPV is the discounted benefits of an investment, less its discounted costs.

The method used to establish the 'merit order' is presented in Figure 1 below, where FRMS is the 'system' level and the flood risk management 'options' range from 'no new investment' to 'improve+'. The management options used for coastal erosion analysis are 'hold the line' and 'no active intervention'.

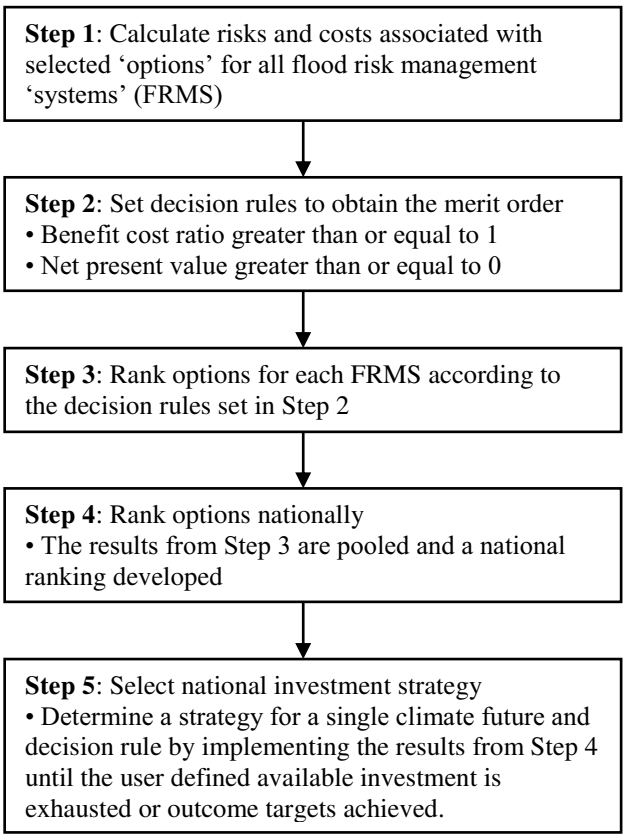

Figure 1. Five steps of the 'merit order' analysis framework for flood risk from rivers and sea, and coastal erosion. Note that FRMS is the 'system' level of analysis, and 'option' is a flood risk management option.

The 'available investment' defined in Step 5 allows the user to define a number of investment ceilings which provide points on a graph of NPV vs cost, allowing the optimum level of investment to be identified. We define the 'optimum', under a given scenario, as the long-term level of investment that would be sufficient over the study period to fund all activity to manage flood and coastal risk where benefits are greater than costs.

For the analysis of flooding from surface water, the 'merit order' method is not applied. Since there is a lack of spatial granularity in the evidence of the response of surface water flood risk under different management options, the analysis for surface water flood risk is carried out at national scale under a do minimum, maintain current risk levels and improve management options.

2.2 Strengths of the approach

The unique strength of this approach is that, at a national level, the analysis is able to rank the costs and benefits of a large number of systems (over 3,000) and a range of different policies, in order to produce credible national scenarios that are subject to a rigorous economic optimisation.

The basis for the approach is a nationally consistent risk assessment, and other national datasets for assets, their deterioration rates and costs of renewal and replacement.

The analysis incorporates results from higher-level consideration of flood risk from surface water, and the potential to reduce the consequences of flooding through flood forecasting and warning. Additional analysis shows how options such as resilience and resistance measures for properties are cost effective in many circumstances. If more properties put these measures in place, this would help to further reduce the impacts of flooding and the associated economic damages. Other approaches which are not yet possible to evaluate within the LTIS analysis might include better land management to reduce run-off, and adapting some coastline to protect inland areas.

2.3 Constraints of the current approach

The main constraint in the economic optimisation approach is that, whilst the total cost of investment over the 50 year period (and hence the annual average cost) is considered to be robust, there are large uncertainties around the timing of investments. The LTIS reports an approximate trend, but there will be peaks and troughs of demand over time because of the need to replace specific assets at specific times. The analysis also assumes typical asset deterioration rates. The long-term risk profile presented in Figure 2 is based on replacing or upgrading assets when they are projected to deteriorate to a specified lower condition grade, based on research on asset deterioration rates. Arguably this is a reasonable assumption when the selected policy is to maintain current standards of protection, but a policy to raise levels of protection might be better implemented sooner if this is economically justified. This produces a cost profile based on investing most heavily to replace and upgrade assets in the longer term rather than in the next 10 to 15 years. Consequently, this defers the possible reduction in risk to the later period. It is reasonable to assume that some investment could be brought forward or delayed.

The analysis cannot precisely optimise asset replacement intervals. In some cases, it could be

beneficial to change the estimated timing of capital investments to achieve higher net benefits. A more precautionary approach to risk management would be to bring forward investments when certain criteria are met, such as assets deteriorating to a specified condition. The alternative is a more adaptive approach, where the timing of investments is designed to 'sweat' the current assets, and new assets are designed to be 'topped-up' in the future to adapt to climate change increasing risk. The current LTIS approach is not able to test different timings of investments and compare precautionary and adaptive approaches.

The current approach focuses on the costs of flooding that can currently be robustly estimated. It considers levels of investment against the costs of future damage avoided. We have excluded economic benefits related to risk to life from the LTIS analysis, due to the difficulty of predicting loss of life from flooding. There is no attempt to consider the effect of flooding on health or family life or other factors influencing investment decisions, nor to consider constraints on funding or the need to prioritise limited resources.

Under a changing climate, widespread flooding such as the events experienced in 2007 could become more common in future. It is difficult to estimate the effects of these events in terms of stretching emergency response capability, and causing disruption to critical infrastructure that could have serious consequences for the wider economy, although these impacts are likely to be disproportionate compared with floods affecting smaller areas. A better understanding of the potential impacts of widespread flooding – including the impacts on infrastructure networks and dependencies – would strengthen the analysis.

Considering the timing of investments, or the wider benefits of flood and coastal risk management investment, might enable the current approach to be deepened; to represent particular aspects of the system in more detail in order to improve our understanding of investment need and timing. However as the LTIS analysis focuses on the benefits of investing to provide, improve and maintain structures, there are constraints around the degree to which it is able to represent non-structural responses to flood and coastal risk. Rather than over-complicate the existing method, a parallel broader analysis could overlap with the existing scope and provide a framework for a more inclusive overview of risk management activities. This could build on the LTIS analysis of resilience and resistance measures to consider a broader range of flood risk management options, based on recently published research [2].

3 What do the investment scenarios show?

3.1 Optimal investment profiles

The investment scenarios indicate that the optimal level of investment in the short term (in the first 10 years) will be around £750 to £800 million (approximately €950 to €1000 million) a year in present day costs. This aligns closely with the government's current investment plans for the period 2015-2021, which is made up of £2.3 billion (€2.9 billion) of planned capital funding from government, alongside targeted external contributions to projects, and assumes that outcomes from non-capital spend (asset maintenance, flood forecasting and warning) are maintained at present levels.

The LTIS optimum investment level is dependent on a set of assumptions underlying this 'baseline' scenario:

- The cost of building defences decreases by 10% by 2021 and remains flat thereafter.
- A medium rate of climate change takes place over the study period.
- Any risk caused by further development on the floodplain is mitigated at the cost of the developer and this cost is not included.

Over the long-term (the 50 year period to 2065), we expect the optimal investment profile to rise from the 2020s to the 2040s to £850 to £900 million (€1070 to €1140 million) a year. This is illustrated in Figure 2. There is scope to influence this profile by choosing different policies, and there may be other ways to determine how costs should be distributed over the next 50 years, so the total cost is an important reference point. Averaged over the study period, this amounts to £860 million (€1090 million) per year.

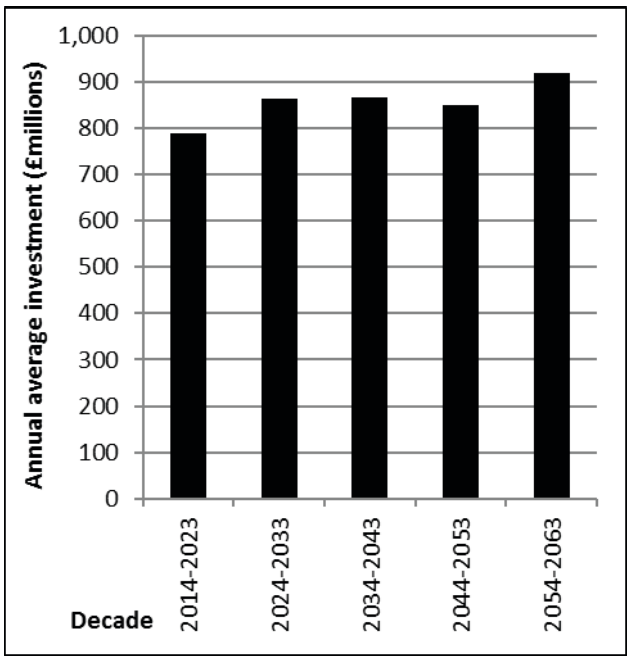

Figure 2. Modelled long-term investment need – annual averages over the next 5 decades (costs in present day terms).

3.2 The benefits of reducing the cost of capital investments

The LTIS optimum investment level is based on the assumption that the Environment Agency will reduce the cost of capital investments overall by 10% between 2015 and 2021 (which the Environment Agency is committed to achieving), and hold costs down after that. The long-term benefit of this is significant. If there were no

improvements in efficiency, the level of annual average optimum investment would increase by 3%. But more importantly, this would mean that the best potential long-term result would be to only hold risk at current levels rather than to reduce it significantly.

Provided this 10% capital efficiency target is met, and that unit costs are held down after 2021, this not only lowers the cost of providing defences, but also increases the number of activities that can be considered cost effective.

3.3 Reducing risk despite the impacts of climate change

It is possible to reduce risk despite the impacts of climate change. LTIS estimates that a 12% risk reduction could be made, cost effectively, by the 2060s if investment continues at the optimum level described above.

By way of comparison, the expected risk outcome if we invest optimally under a 'high' climate scenario is a 4% reduction. A 'high' climate change scenario would also drive up costs, increasing the long-term annual average investment from £860 million per year to £920 million (€1160 million) per year.

3.4 The impact of uncontrolled development on the floodplain

Future development on the flood plain will also be an important risk to manage. Our baseline scenario assumes effective development control in future. The comparison is a (worst case) scenario where development is not controlled and numbers of properties in the flood plain increase in line with national population projections (increase of 30% by 2065).

Without effective planning controls, pressure to build more homes would add up to 16% to the cost of optimal flood protection compared with the 'baseline' scenario. Even at this increased level of investment, the overall flood risk would not reduce over time. This scenario is unlikely but used as a 'worst case' comparison.

4 Lessons and challenges from recent flooding

Recent flooding in the north of England has led to new questions being asked about flood risk management in England. More than 16,000 homes were flooded in Cumbria and Lancashire in December 2015 as a result of storms which established new United Kingdom rainfall records over 24-hour (341.4mm at Honister Pass, Cumbria) and 48-hour (405.0mm at Thirlmere, Cumbria) timeframes. New peak flow maxima were established for many large rivers with records longer than 45 years, for example the Eden, Lune and Tyne on the 5th/6th and the Nidd, Wharfe, Aire and Irwell on the 25th/26th [3].

In response the government has established a National Flood Resilience Review, to assess how the country can be better protected from future flooding and increasingly extreme weather events. It will focus on four key areas: updating our climate modelling and stress-testing the nation's resilience to flood risk; assessing the resilience of our important infrastructure like electricity substations; our temporary defences; and our future investment strategy [4].

The review will be informed by the existing LTIS analysis but is also likely to raise questions for the next iteration of analysis. Though entirely speculation, these questions could include:

- What are the costs of plausible but unlikely 'reasonably foreseeable worst case' 'H++' scenarios?
- What is the risk to infrastructure assets, networks and their interdependencies?
- What role can temporary and demountable community defences, and/or property level protection play in reducing residual flood risk?
- What is the potential contribution of natural flood management (working with natural processes) to flood risk management?

5 International comparisons

International comparisons of flood risk management governance and investment approaches demonstrate a huge diversity between countries in terms of the number and types of actors involved, partly related to the administrative structures and cultures of the countries [5]. A review [6] of existing decision support tools in the field of long-term flood risk management identified 19 such tools predominately developed in Germany, The Netherlands and United Kingdom as well as some other European countries.

The closest comparison between investment planning approaches at a national level is between the United Kingdom and The Netherlands. Both countries balance economic benefits and costs with standards of protection in making decisions, but with very different emphases. Both suffered disastrous flooding in 1953, with the impacts in The Netherlands making flood risk an existential threat to the country. From 1960 onwards, the Delta Commission was instrumental in using scientific analysis to inform flood risk policy in The Netherlands. It determined levels of acceptable risk, a process which was finalised on a national scale in 1996 with the Flood Defense Act.

In 2008, a special advisory group set up by the national government to examine the challenges of the future, the (second) Delta Commission, proposed a new flood risk management approach, with protection standards based not only on cost-benefit analysis but on loss-of-life calculations as well. Whilst an assessment of economically efficient flood protection standards has been described [7], the Delta Programme 2015 [8] set out new standards for flood risk management in the Netherlands based on safety: that everyone living behind dykes and dunes in the Netherlands can count on a protection level of 10^{-5} by 2050 (meaning that the probability of dying as a result of a flood is no higher than 1:100,000 a year). This contrasts with the United Kingdom where there are no target standards of

protection, and government policy is to compare expected whole life benefits and whole life costs of a scheme. It is in this context that the LTIS analysis provides a powerful national tool, as it is able to optimise investment by assessing and adding investments in 'merit order', so those that bring the most benefit in relation to costs are added first.

6 An opportunity to collaborate

In order to develop the evidence for future investment in flood and coastal risk management further, the Environment Agency is now seeking a more open, collaborative approach to develop LTIS and strengthen it further as robust, independent, world-leading evidence. It will invite a number of leading experts to help steer the approach to long-term investment plans for flood and coastal erosion risk management. The aim is to form a diverse, expert panel driving the thinking behind the next stages of LTIS work, and where the willingness and capacity exists, to work in collaboration to deliver it, sharing ideas across disciplines.

Collaborating with academic and industry partners will enable experts to share insights and offer new perspectives, access a wide range of funding sources, and potentially broaden the research base, giving it the capacity to explore more radical challenges and approaches.

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