Unpacking climate governance in relation to climate risk

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This document relates climate risks to costs (and, consequently, benefits) of interest to governance.

0.1 Introduction

Risk is usually defined as the product of the probability of an event and the consequences of the event. It is a relative index used to judge the relative importance of events. However, to be useful, the index needs to be made consistent. The probability of an event relates specifically to the type and magnitude of a hazard while the consequences (impacts) relate to the costs when a hazard occurs. Such costs are often determined in dollars but could be determined as other continuous (or pseudo-continuous) metrics. Impacts arise from the degree of exposure to the hazard and/or subsequent perturbations caused by the hazard (cascading and compounding effects), the vulnerabilities to being affected by exposures, and the potential for responses to create their own consequences/costs. General use of the term 'risk' can create confusion when trying to understand the links between hazards and costs.

There are a multitude (network, cascade) of pathways between a hazard and ultimate impacts. From a governance perspective, the aim is to minimise the overall costs of the portfolio of hazards - costs of mitigation and preparation (let's call these the preparatory or input costs) plus costs of response and recovery to the impacts (resilience or output costs). Resilience costs are the result of residual risks, which are the risks remaining after interventions to reduce hazards, exposures and vulnerabilities, combined with the preparation for managing impacts, i.e. preparing for response and recovery. Preparatory costs are the interventions and preparation prior to impact. Successful governance manages the total costs of mitigation and preparation (inputs) and response and recovery (outputs) across all hazards, which includes being aware of and managing positive and negative interactions between interventions. However, entities in governance need only be concerned with inputs and outputs at the scale of their interest. For example, the federal government may only require an understanding of the financial costs of inputs and outputs to achieve an optimal solution, compared to a local business that will need to know how interventions will be implemented (people, skill, materials, social management etc.) in protecting their interests.

Decision-making is not straight forward because of the social dimension and attitudes of individual actors within entities. This is treated as an aside in the following illustration but will need to be made central in understanding the strengths of interactions between governance entities.

This document aims to illustrate how to advance beyond consideration of risks to the issues of governance relating to costs and benefits, neither of which need to be measured solely as monetary. It is divided into four sections:

i) Analytical pathways converting hazards to residual risks,

ii) Reframing risk management as costs,

iii) Integrating governance across a portfolio of hazards, and

iv) Important issues for further consideration.

0.1.1 Illustrative example

The following example is used for framing the illustrative calculations and graphs in this paper.

Flooding is topical and a tangible climate threat. Water flows in Australia are dictated by average daily rainfall along with storms (quantity and duration of downpour) that result in increased free-flowing water in catchments. The instantenous volume of water carried by the river is a hazard. Exposure of some factor or asset of interest, e.g. dwellings, will be determined by the height of the river given the instantaneous volume of water. Such exposures are now readily mapped using geographic information systems. Exposure may be moderated through the building dams downstream of common heavy rainfall events, the building of levee banks around assets. Such levee banks would be regarded as adaptations. They may also be maladaptations if they displace the water and expose other areas that would have otherwise been safe. Given that levee banks may be breached, safety of the dwellings will be dependent on the likelihood of such breaches, either through failure of the bank or from the volume of water exceeding that which can be excluded by the bank.

Should dwellings be exposed, they may be made less vulnerable to impacts if they were built on stilts to keep parts of the dwelling above the water. Should a dwelling be flooded, costs may include loss of life, belongings and/or dwelling depending on the response, and recovery will depend on household wealth, insurance and available support and services. Further, response and recovery may be impacted by other impacts of the flood, such as road infrastructure, utilities, and scale of impact on the community.

Thus, from a governance perspective, the probability of events is in managing hazards and exposure, while the impacts are more contingent on vulnerability, response and recovery. Moreover, the concept of cascading risks is more relate to how direct impacts (vulnerability) affect other more distally-related assets, services or some other factors.

0.2 Analytical pathways converting hazards to residual risks

0.2.1 Hazards

Floods are often talked about as 1 in 10 year, 1 in 100 year, 1 in 1000 year floods. These expressions are often based on experience, assuming a world is unchanging in geological time. However, they are expected to reflect probabilities of occurrence, i.e. how often the maximum river height in a year may occur over hundreds of years (Figure 1). People will be used to regular river flows around the median annual maximum rainfall events, indicated by the mode in the figure, and their planning will take this into account. Greater than 1 in 30 year floods are generational in experience. For assessing risk, the relevant probability of a prolonged storm (translated to river height) is the probability that the annual maximum flow is equal to or exceeds a relevant river flow/height.

Under climate scenarios considered by the IPCC, catchments may experience two kinds of changes in their flood regimes - increase in the median annual maximum river height, and/or increase in the likelihood of very high maxima (spread). Figure 2 illustrates how annual maximum river height may change for 1 in 10

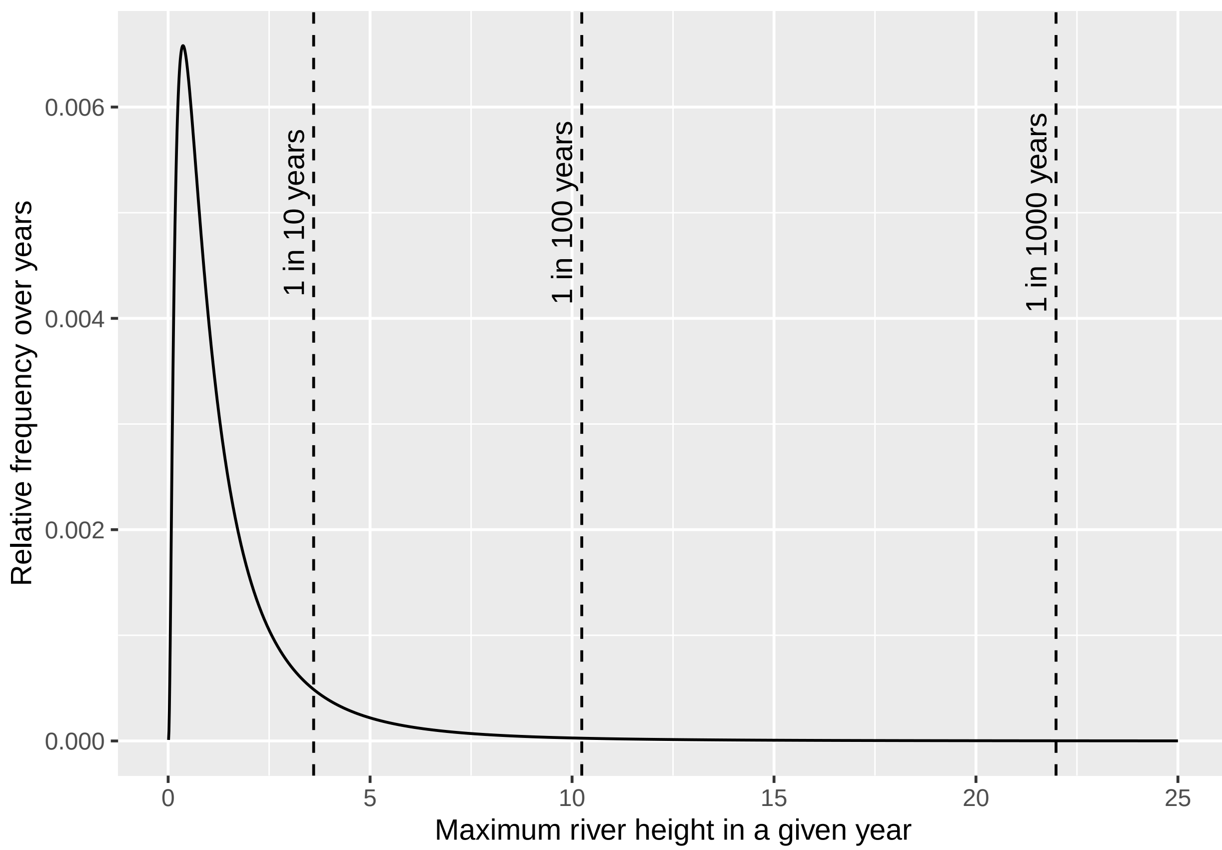


Figure 1: Probability density function for annual maximum river height, showing floods colloquially termed 1 in 10, 100 and 1000 year floods

year floods (scale of river height is illustrative, i.e. not based on projections). This illustrates a dynamic nature of the probability of hazardous events.

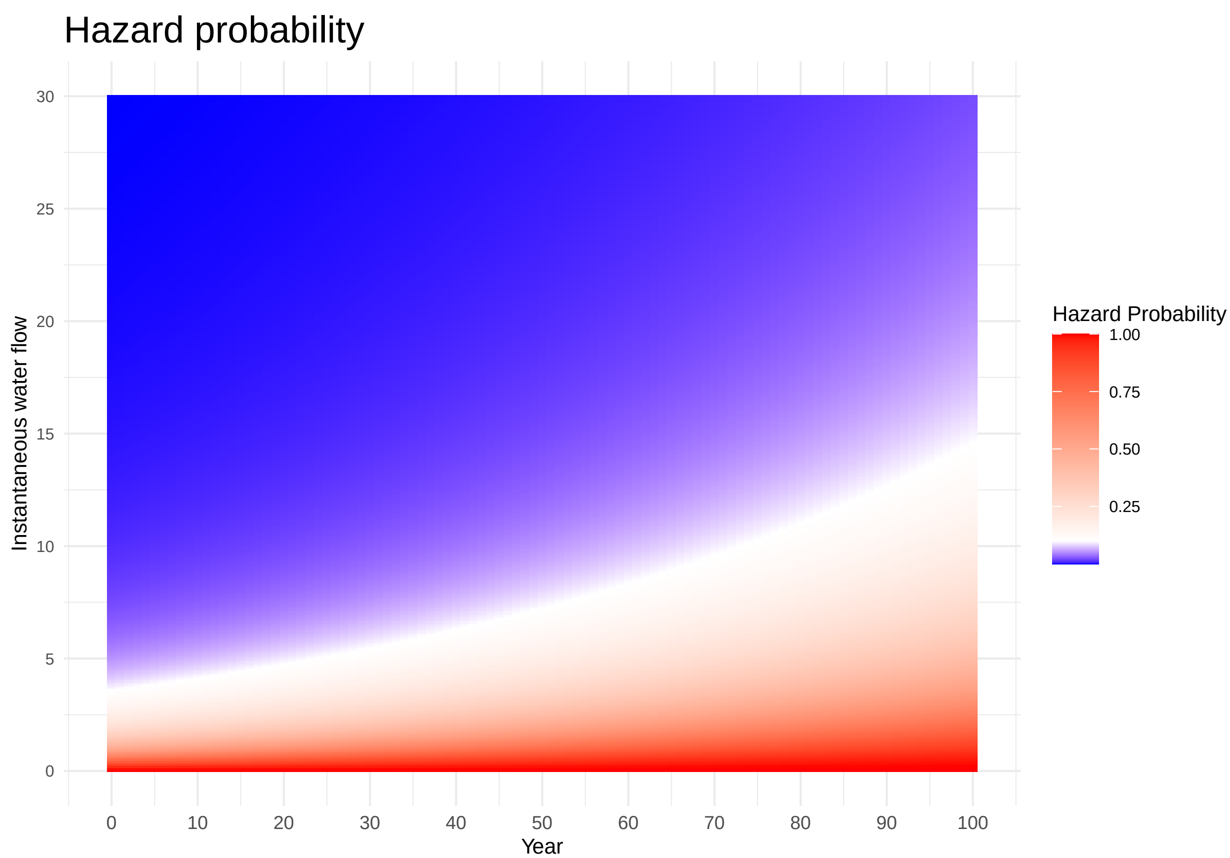
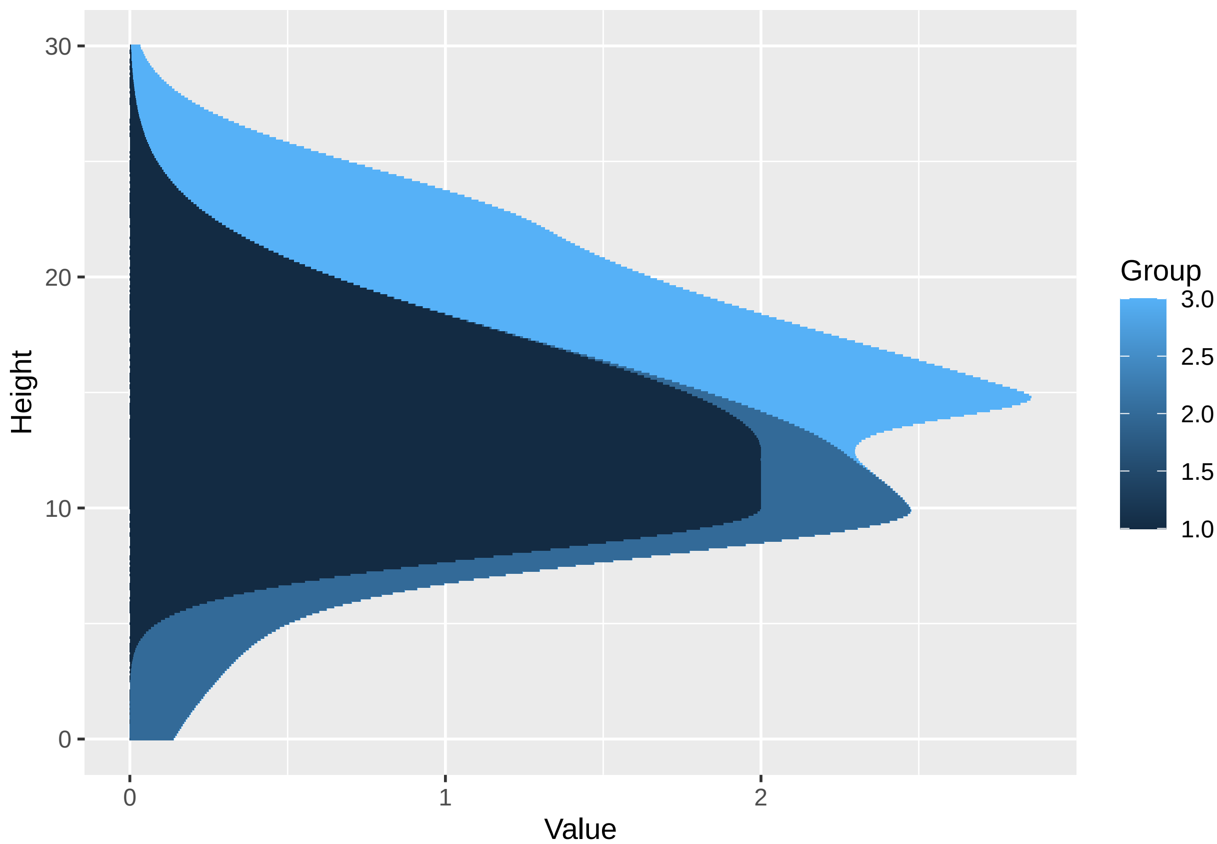


Figure 2: xxx

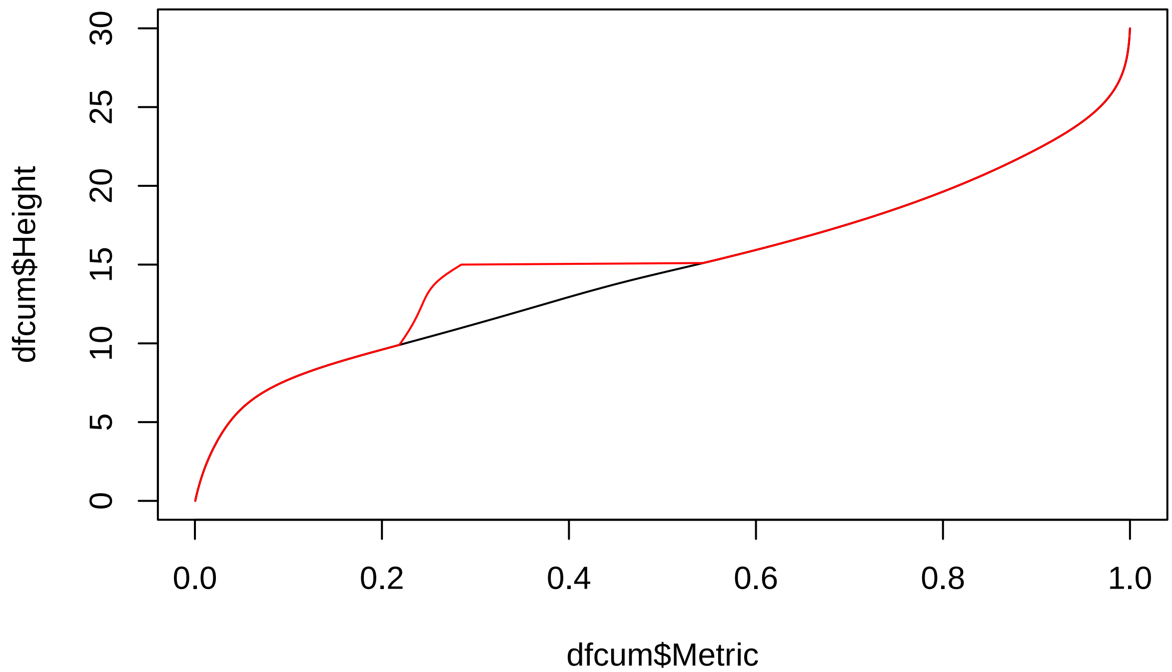
0.2.2 Exposure

Exposure relates to the degree to which assets, services or some such (collectively termed 'objects') are exposed when a level of hazard is reached. In the catchment example, exposure may be considered to be the topographic contour of the water level in a place (often termed 'river height'). In this case, exposure can be moderated by trapping the water upstream in dams and releasing it slowly, modifying water retention in the landscape, and/or protecting assets via levees. The first part of exposure is, consequently, the probability of an area being exposed after moderation of the hazard. For governance, the second part of exposure is critical which is the accumulated value of the objects exposed to the hazard. Note, partial control of hazards (dams and levees) can yield sudden increases in exposure as events increase in their magnitude beyond the protection of those constructions. In terms of adaptation, costs of adding to such controls may also not be linearly related to the magnitude of reduction in hazard. For example, the cost of increasing the height of a levee is proportional to the volume of materials and construction required rather than the height.

The distribution and value of objects will change over time. For example, the number of dwellings will likely increase in popular areas. As part of an adaptation strategy, dwellings may be removed from flood-prone areas.



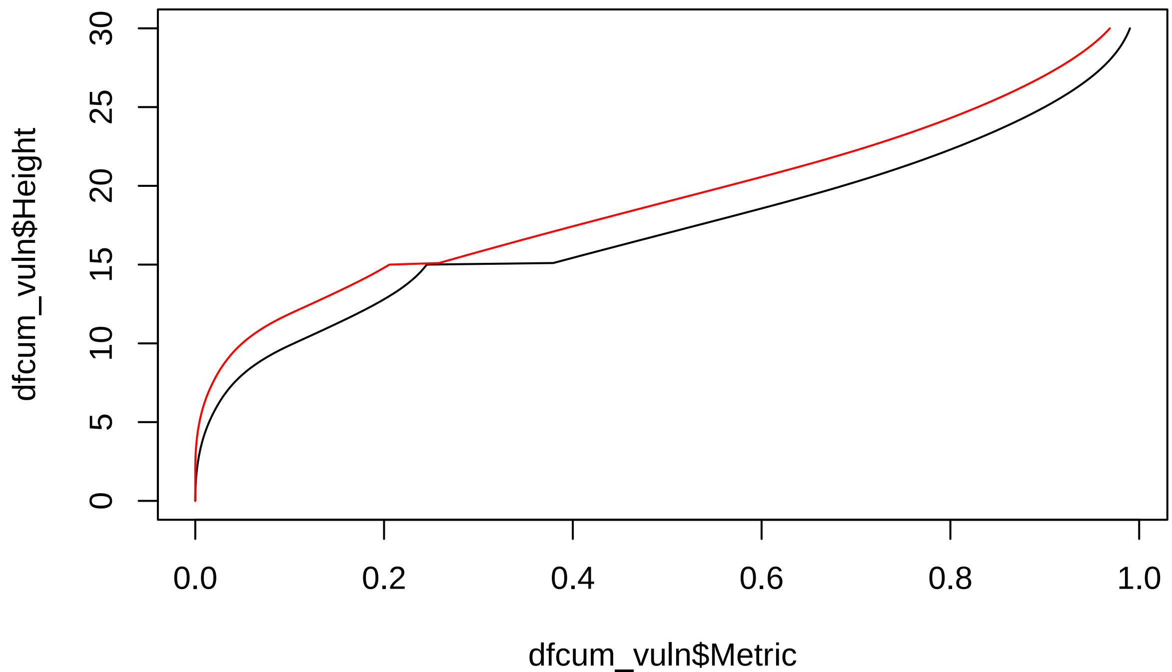
Height
Value
Group
3.0
2.5
2.0
1.5
1.0
30
20
10
0
0
1
2



0.2.3 Vulnerability

Impacts on objects are determined by their vulnerability once exposed. In the flood example, vulnerability is the degree to which dwellings would be rendered uninhabitable. A dwelling built directly on the ground would remain habitable if the depth of the flood at the dwelling was less than a meter up the wall of the house. Above three meters and a single story house would be difficult to salvage. Adaptations to reduce vulnerability may be to have a ground floor able to withstand a river flowing through it or to modify the dwelling in such a way that complete inundation would not diminish potential for salvage. In this example, vulnerability changes linearly from 0 if the water is lapping at the door to 1 (loss of house) if the depth of the water at the house exceeds 5m. The cumulative loss of value to the community of a flood (impact) is the product of vulnerability by value of the dwellings in each group exposed to the flood. The risk to the community is the probability of attaining a river height multiplied by the impact.

Figure - impact



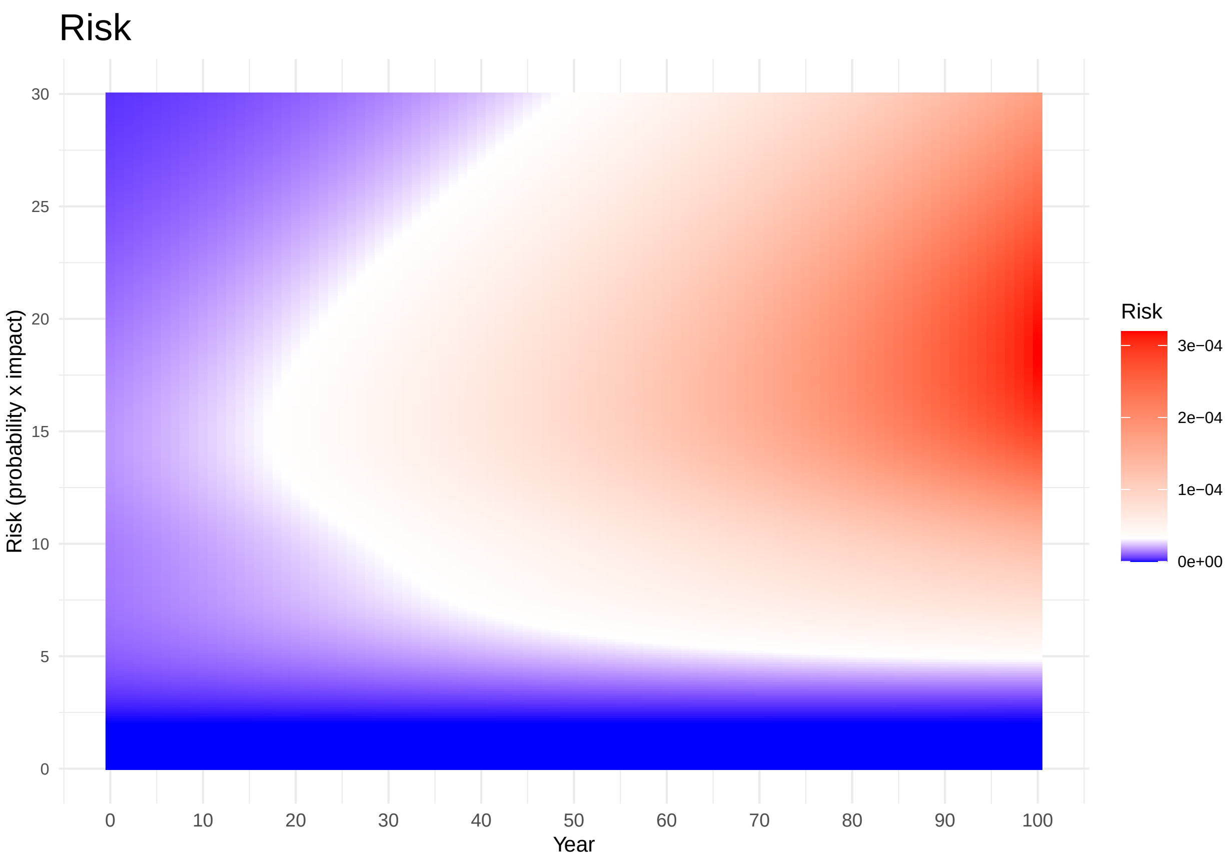
Risk is then the impact multiplied by the probability of an event.

0.3 Reframing risk management as costs

Plots of risk over time given different flood levels is a coarse, heuristic tool for mapping and/or testing adaptation options. Decision-makers rely on simplified metrics. A suitable metric in the example here is the average annual cost of recovery given the risk profile. Over many years, the probability of hazards would be expected to play out as relative frequencies of events. If the cost of recovery over many years is budgetted for as an average annual cost then it can be used for comparative purposes as to whether adaptation strategies are affordable and appropriate.

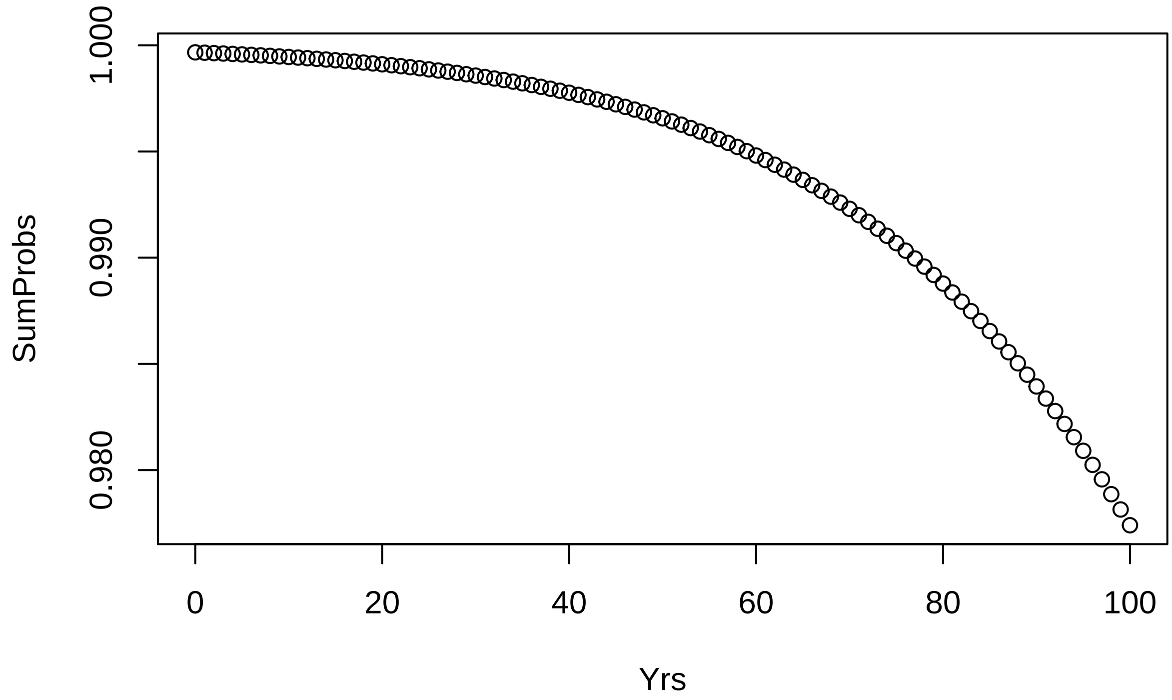
The risk example above is recalculated as an average annual cost of recovery, which is the carriage of residual risk.

```
Yrs<-unique(df_risk$x)
SumProbs<-unlist(lapply(Yrs,function(y,h){sum(h[h$x==y,"pEvent"])},df_H))
plot(Yrs,SumProbs)
```

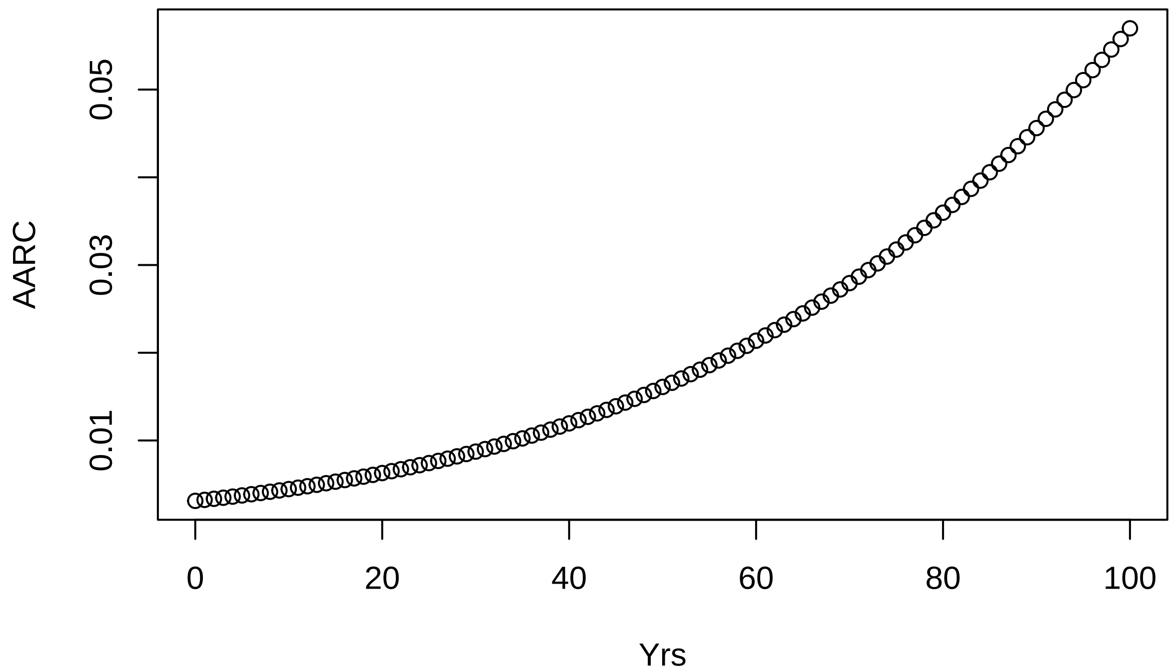


Risk
Risk (probability x impact)
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Year
Risk
3e−04
2e−04
1e−04
0e+00

Figure 3: xxx




```
AARC<-unlist(lapply(seq(1,length(Yrs),1),function(i,y,r,denom){sum(r[r$x==y[i],"z"])/denom[i]},Yrs,df_r
plot(Yrs,AARC)
```



0.3.1 Integrating across risks arising from a single hazard

0.4 Integrating governance across a portfolio of hazards

0.5 Important issues for further consideration

0.5.1 Attitude to risk

Risk rejection, tolerance, aversion, avoidance
plot how this would look given levels of hazard