Imagining flood futures: risk assessment and management in practice

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The mantra that policy and management should be ‘evidence-based’ is well established. Less so are the implications that follow from ‘evidence’ being predictions of the future (forecasts, scenarios, horizons) even though such futures define the actions taken today to make the future sustainable. Here, we consider the tension between ‘evidence’, reliable because it is observed, and predictions of the future, unobservable in conventional terms. For flood risk management in England and Wales, we show that futures are actively constituted, and so imagined, through ‘suites of practices’ entwining policy, management and scientific analysis. Management has to constrain analysis because of the many ways in which flood futures can be constructed, but also because of commitment to an accounting calculus, which requires risk to be expressed in monetary terms. It is grounded in numerical simulation, undertaken by scientific consultants who follow policy/management guidelines that define the futures to be considered. Historical evidence is needed to deal with process and parameter uncertainties and the futures imagined are tied to pasts experienced. Reliance on past events is a challenge for prediction, given changing probability (e.g. climate change) and consequence (e.g. development on floodplains). So, risk management allows some elements of risk analysis to become unstable (notably in relation to climate change) but forces others to remain stable (e.g. invoking regulation to prevent inappropriate floodplain development). We conclude that the assumed separation of risk assessment and management is false because the risk calculation has to be defined by management. Making this process accountable requires openness about the procedures that make flood risk analysis more (or less) reliable to those we entrust to produce and act upon them such that, unlike the ‘pseudosciences’, they can be put to the test of public interrogation by those who have to live with their consequences.

Keywords: risk management; risk analysis; flooding; simulacra; Baudrillard; simulation

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One contribution of 12 to a Theo Murphy Meeting Issue ‘The sustainable planet: opportunities and challenges for science, technology and society’.
1. Introduction

But what about ideas ‘beyond the fringe’—the illusory comfort and assurance of the pseudosciences? Here there is less scope for debate—both sides don’t share the same methods or play by the same evidence-based rules. I’ve not found it fruitful to have much dialogue with astrologers or with creationists.

(Lord Rees of Ludlow, 2010 Reith Lecture The Scientific Citizen)

This paper is concerned with the relationship between science, policy and the future. The original notion of sustainable development [1] saw development as sustainable if it meets the needs of present generations without, in so doing, compromising the ability of future generations to achieve their needs. In essence, it makes an explicit linkage between the activities of the present and their implications for the future. It is not surprising, then, that much scientific effort has been put into predicting what the future would look like (e.g. the work of the Intergovernmental Panel on Climate Change), if we continue as we are at the present (i.e. business as usual) or if we change what we do in the present (i.e. we follow different possible scenarios). Such ‘futures’ constitute a form of cognitive evidence that can be used to justify material interventions (e.g. actions to change behaviour; engineering construction projects; etc.) in the present so as to secure a more sustainable future. Such interventions make the future different, not our cognitive understanding of the form that the future will take. Yet, the cognitive understandings that we generate to inform material intervention involve a radically different relationship between scientific knowledge and its object (i.e. a different epistemology) if the object is the future, because the future is unobservable in principle. This unsettles the conventional rhetoric of ‘evidence-based’ policy and management. The ‘evidence’ does not come from observations but a series of predictions of what the future might look like, commonly grounded in some form of numerical simulation. Because such observations of the future are unobservable, does this make our predictions ‘pseudoscience’? How do numerical simulations of the future, as a form of evidence-based policy-making, differ from predictions of the future made by astrologists or creationists? We might expect that, as the introductory quote implies, the answer is in the methods and the evidence-based rules that we have come to deem as more acceptable than others in predicting the future. But, what are these methods and rules, how do they become deemed as acceptable and, crucially, what effect do they have upon how the future might be made sustainable?

We address these questions of how it is that the future is made ‘knowable’ through a focus on flood inundation in England and Wales. We explore what we call a ‘suite of practices’ that have developed at the nexus of science, public policy and risk management in order to make flood futures known in ways that inform interventions now. We argue that central to this nexus is a calculus, grounded in accounting practice, that is both financial, concerned with the optimum use of scarce public resources, but also scientific in the sense that it relies upon computation which renders both past events and possible futures calculable. The necessity arises because there are so many possible futures for flood inundation

1Note the origins of the work ‘account’ in the Latin ‘computare’.

Phil. Trans. R. Soc. A (2011)
that could be produced. We have no a priori reasons to choose between different futures as the evidence that might inform that choice has yet to be realized [2]. Rather we show that the suite of practices that has evolved around flood risk analysis is designed to constrain what the future is allowed to look like, through ‘auxiliary’ assumptions that allow the past to inform the future; that restrict what is modelled, by whom and how; and which allow the future to break from the past but only in very particular ways. The contingency arises because the supposed objectivity of the financial underpinning of the accounting process has to be forced to travel both geographically, and into the future, and so has to be extended to all elements of the practice.

Our analysis begins by drawing upon two very different literatures that underpin our arguments. The first is concerned with the notion of ‘hazardscapes’ [3] and the ways in which interventions aimed at reducing risk often have a more complex consequence. The second uses literature on the nature of mathematical modelling to argue that these interventions are associated with a suite of practices. Such practices challenge some of the supposed relationships between science and policy in risk management. We then illustrate these issues through a detailed account of flood risk in the UK to show that understanding how the future is made through practices of accounting is vital to changing those practices in the pursuit of more sustainable futures.

2. Hazardscapes: from interventions to practices

In 1942, Gilbert White published a seminal work Human Adjustment to Floods. This interrogated the practice of flood risk management in the USA, both historically and with reference to current flood risk management policies. In so doing, it defined an era in which we have recognized that flood risk is not only a function of the probability of there being a flood event, but also the consequences of an event. White [4] examined a series of activities that lead to changes in consequence (e.g. development in floodplains) and broadened the range of measures that might be used to reduce flood risk, to add management of consequence to reduction of probability. Among many important observations by White, one is critical, what we have subsequently come to define as the ‘levée effect’. White [4, p. 142] wrote: ‘...levées may promote some reshuffling of land use. They tend to discourage intensive occupation of unprotected zones, and to increase the stability of land use within the protected area.’ Faced with a choice between living in an undefended floodplain and a defended floodplain, the latter would prevail. While the initial intervention may reduce the probability of inundation and reduce risk, no flood defence can provide perfect protection against all floods. There are two reasons for this. First, all defences have a probability of failure that is a function of their condition of maintenance. Second, flood defences can only provide protection to floods of a certain magnitude, normally set probabilistically or, as the inverse of probability, as a return period, the average time between events of a given magnitude. If a defence is designed to have a standard of protection of 100 years, and provided the defence is maintained to deliver that standard of protection, the defence will protect against flood flows up to those with a return period of 100 years. Unfortunately, evidence has shown that 100 year return period protection tends to be interpreted as total flood...
protection by existing and potential floodplain dwellers (e.g. [5–7]) and that this interpretation allows for the evolution of consequence in ways that may reduce the reduction of risk resulting from the defence, possibly even increasing it.

White’s observation is important because it counters the linear view of risk management: quantification of risk (both probability and consequence) followed by intervention to reduce risk. Rather, it implies that interventions change the spatial distribution of risk which, with time, is consequential for the process of change. This notion has been widely explored in the risk literature, most recently in the notion of ‘hazardscapes’ [3]. The latter ‘fuses the material and discursive aspects of how hazardous spaces are produced, contested, and struggled over’ [3, p. 570]. In a case study of flood risk in Pakistan, Mustafa [3] describes how science-centred accounts of management, concerned with bringing a flood-prone river under hydrological control, have come to dominate at the expense of other accounts, such as those that are experiential, and grounded in the understandings of those who live with risk. The hazardscape for a flood hydrologist is focused upon bringing the hydrological cycle under control. For a floodplain dweller, the hazardscape comprises the multitude of risks that are experienced as part of the business of day-to-day life: hazards are ever-present, hydrological hazards may only ever be intermittently present. Mustafa [3] accounts for the dominance of scientific accounts and their material manifestation in terms of political ecology (see also [8–10]). But the work also points to the need to understand why it is that scientific accounts take on particular forms. The decisions to construct a levee or to embark upon upstream land management are both decisions to make interventions in a hazardscape. Such decisions aim to prevent certain kinds of futures from happening. However, there are a multitude of interventions that could be considered, each of which require and are sustained by particular (and overlapping) suites of scientific practices relating to how data are collected and used, how mathematical models are developed and implemented, the assumptions made regarding possible future scenarios and the weight given to non-conventional sources of knowledge such as the information provided by flood victims. Below, we identify the suite of practices that has not only become dominant, but that has also become regulated, in accounting for current and future flood risk in the UK. The notion that a ‘suite of practices’ exists and has impacts in terms of how it causes interventions to take on particular forms is troubling, precisely because it unsettles the assumption that scientific analysis can unambiguously inform risk management. Rather, and as we evaluate below, risk management necessarily and contingently defines the suite of practices that scientific analyses can, and even must, adopt.

3. Practicing the future: representation and simulation

Numerical simulation is central to risk analysis in general and flood risk analysis in particular: in order to understand the range of possible futures that might unfold, what the hazardscape might look like under those futures and hence how to intervene; it is necessary to use mathematical models that identify the probability of a particular event occurring and subsequently its consequences. Winsberg [11, p. 108] outlines the essence of a numerical simulation model as a hybrid ‘offspring of theory’: the physical world can be described using theories, which

Phil. Trans. R. Soc. A (2011)
can be expressed as differential equations; but these equations are not solvable on their own and have to be made computable. In doing this ‘idealizations, approximations, and even self-conscious falsifications are introduced into the model’ [11, p. 108]. Winsberg argues that numerical simulations can then be viewed in one of three ways: (i) metaphorical; (ii) representational (i.e. a direct mimic of a real world system, like an experiment); or (iii) some kind of third, or hybrid, entity. The latter recognizes a difference between a set of general theories that might refer to a problem or situation and the more complex and creative steps that are needed to make a local (in space or time or problem domain) simulation model [2,11,12]. Winsberg argues that credibility in simulation models then derives not only from the extent to which they are true to their general underlying theories (e.g. whether a flood model conserves water mass), but also their credibility with respect to previous applications: ‘the credibility of that model comes not only from the credentials supplied to it by the governing theory, but also from the antecedently established credentials of the model building techniques developed over an extended tradition of employment’ [11, p. 122]. Through this tradition of employment, simulation models may go on to have a life of their own [11]. Research has shown (e.g. [13,14]) that credentials are rarely established through apparently simple activities like model validation (e.g. comparison of observed and predicted quantities) not only because such activities are philosophically more complex than might be assumed but also because credibility is defined by a suite of other practices such as informed judgement and convenience, including the ease with which empirical adequacy might be enforced [14]. Models evolve from representing the world in a way that allows numerical experimentation to constructing the world in ways defined by the modelling practices accepted as ‘tradition’ (see [15]).

Surrounding numerical simulation is the development of a suite of practices that sustain simulation’s ongoing contribution to risk analysis. Two issues arise. First, as different suites of practice may lead to the identification of different futures, and because the future is not yet knowable through more conventional methods (e.g. observation), then understanding the nature of those practices is critical. Second, it is important to consider whether a suite of practices develops through and out of scientific analyses, in ways that go on to inform the management of risk; or whether a suite of practices becomes framed by risk management in ways that challenge the supposed autonomy and integrity of science as separate from policy.

4. The flood hazardscape of England and Wales

In England and Wales, four to five million people, two million homes and businesses, assets valued at £250 billion, are currently estimated to be at risk from flooding.\(^2\) Flood risk management is split between a UK government department (the Department for the Environment, Food and Rural Affairs, Defra), responsible for overall policy and resource allocation and a non-departmental public body (the Environment Agency of England and Wales, the EA) with operational responsibility for flood risk management, that reports to the UK’s parliament through Defra. In 2007/2008, the EA employed around

\(^2\)Figures from Defra factsheet: ‘Flood and coastal erosion management’.
12,500 staff in England and Wales, with a budget of £1 billion.\(^3\) Water courses are designated as either ‘main rivers’ or ‘ordinary watercourses’ and the EA is empowered but not legally obliged to manage flood risk from main rivers. Ordinary watercourses are managed by a wider set of both public (e.g. local council) and private (e.g. water company) authorities but by far the majority of investment in flood risk management, and associated activities, is undertaken by the EA. It is the EA’s responsibilities that are the focus of this paper. As the operational authority, it is responsible for commissioning risk analyses, which commonly involve numerical simulation and the collection of supporting data, and using them to decide management strategies and to commission interventions that modify the hazardscape and, in so doing, shaping how future flood events are realized.

The practices associated with simulation and intervention are informed by a combination of both generic government policy and specific decision-making, called appraisal. The current generic policy regarding flood risk management in the UK was influenced by a policy shift in 2005 *Making Space for Water* \(^{[16]}\). This includes alternatives to traditional engineered defences (e.g. levées) such as more careful land use planning, catchment-wide analysis of flood risks and greater use of rural floodplains as washlands. The policy shift has been interpreted into its implications for risk analysis and management, labelled as ‘appraisal’ \(^{[17]}\) after stakeholder consultation. Defra \(^{[17]}\) states that management decisions must follow guidelines in HM Treasury’s *Green Book* \(^{[18]}\) which specifically requires the application of cost–benefit analysis (CBA) ‘to quantify in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value’ \(^{[18, p. 4]}\). The CBA: may be modified for distributional impacts (i.e. the differential impacts of options on society) and relative price changes; must discount future costs and benefits to obtain present values; adjust for optimism bias (e.g. underestimation of costs); and consider unvalued impacts using weighting and scoring where appropriate.

HM Treasury \(^{[18]}\) requires a risk-based approach to the evaluation of costs and benefits and Defra \(^{[17]}\) interprets this by defining risk as the product of probability and consequence ‘to enable a consistent and objective comparison of different combinations of consequences and probability to be made between different locations’ \(^{[17, p. 20]}\). HM Treasury \(^{[18]}\) sets the time scale over which costs and benefits should be established as the lifetime of the assets associated with the options being considered and Defra \(^{[17]}\) sets this as 100 years. Likewise, HM Treasury \(^{[18]}\) recognizes that climate change may be particularly important for the appraisal of long-term projects and Defra \(^{[17]}\) therefore requires that the changes in risk due to climate change must be assessed over the whole life of an option. Critically, to guarantee the best return on investment in flood risk defence to the nation, Defra \(^{[17]}\) requires a hierarchical approach in which national scale assessments and regional scale assessments of risk are comparable and used to target more detailed assessments or appraisals. Defra \(^{[17]}\) recognizes that those costs and benefits that cannot be established in non-monetary terms should be recognized, using multi-criteria techniques such as weighting and scoring, not as an alternative to CBA but an extension of it. The critical linkage from Defra \(^{[17]}\)

\(^{3}\)Description and figures from the EA Annual report and accounts 2007–2008.
back to Defra [16] occurs in two senses. First, it is recognized that appraisal should not just involve the reduction of probability, such as through reducing the frequency of flood inundation through flood defence, but also the reduction of consequence through increases in resilience. Second, it recognizes that appraisal of the options for an individual intervention may produce too many interventions at the national scale given available investment resources. Thus, a series of outcome measures and targets are used to prioritize those individual projects with positive appraisal outcomes. This allows decisions on which interventions to fund to be informed by the wider range of outcomes that might follow from flood risk management identified in [16].

The EA [19] operationalizes the Defra [17] guidelines in its Flood and Coastal Erosion Risk Management Appraisal Guidance. This is the detailed document that instructs EA staff and their consultants on how to implement government policy. It is set out as a sequential set of tasks to be informed for the detailed assessment of a project deemed by strategic analyses to be a candidate for intervention (table 1). Central to the steps in table 1 is the use of numerical simulation in a risk analysis that justifies, prioritizes and eventually decides on what a particular intervention should involve, primarily associated with the identification of probabilities and consequences in step 1 and leading to the ‘do nothing’ scenario in step 3, but also the assessment of the costs and benefits of different options in step 4 and beyond. This simulation is generally not undertaken by the EA but by consultants sub-contracted by the EA to undertake specialist analytical or modelling work [20]. Their risk analysis involves a suite of practices that is constrained in two important senses. First, the cascade of Treasury guidelines through Defra policy and into EA operational guidelines frames the form that analysis should take and we illustrate this below. Second, an additional set of guidelines (e.g. [21]) have developed to constrain practices through the joint Defra/EA research and development programme in Flood and Coastal Erosion Risk Management. Interviews with consultants and consideration of this guidance [20] show that analysis is constrained to particular software packages, and these are broadly hydrological (concerned with estimation of the probabilities of flows with different magnitudes) and hydraulic (concerned with determining the number and nature of floodplain uses (e.g. residential properties) exposed to a given flow).

For hydrological analysis, to determine the probabilities of floods of different magnitudes, the dominant software package used is WIN-FAP, a computer-based version of the Flood Estimation Handbook (FEH) [22]. There are two primary sets of methods associated with the FEH: (i) estimation of the probabilities of rainfalls of different depths and a means of transforming rainfall estimates, including those obtained from historical records of rainfall, into river flow estimates, updated in 2006 to the revitalized rainfall-runoff method (ReFH) [16]; and (ii) the statistical method, well suited to locations with longer records of river flow, where the direct analysis of the river flow time series is used to estimate the probabilities of a range of different flows. The rainfall-runoff method can be traced to the Flood Studies Reports (FSR), published from 1971. The FEH brought all the reports together into a single framework and updated the data used to drive and to parametrize the models on the basis of the larger number of flood events that had been instrumented by the late 1990s. The result at this stage is a series of probabilities associated with events of a given magnitude. As these are based primarily upon...
Table 1. Steps in the appraisal of flood and coastal erosion risk management interventions.

<table>
<thead>
<tr>
<th>step</th>
<th>content</th>
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<tbody>
<tr>
<td>(1) understand and define the project; identify the problem and key issues; establish the appraisal period; set the boundaries</td>
<td>sets the length of time over which risks are to be determined as 100 years and the geographical boundaries of the assessment; on this basis, step 1 establishes the probability of flooding and how it might change through time, its consequences and how these might change through time.</td>
</tr>
<tr>
<td>(2) set the objectives</td>
<td>if step 1 concludes that the appraisal should continue, this step states the objectives, including linking them to environmental assessments and stakeholder engagement.</td>
</tr>
<tr>
<td>(3) identify the project type and the baseline</td>
<td>this sets out the project type (e.g. to meet legal duties, to invest in an existing asset, to address a strategic need) and the baseline against which possible interventions should be assessed; for CBAs this is ‘do nothing’, but allowing for possible future changes in risk, specifically those associated with climate change.</td>
</tr>
<tr>
<td>(4) identify, develop and short-list options</td>
<td>this is a screening stage in which all possible options are identified, screened to exclude non-starters and developed into a short-list for detailed appraisal.</td>
</tr>
<tr>
<td>(5) describe, quantify and value costs and benefits</td>
<td>for each option, the benefits accruing from reductions in flood damages are quantified, taking into account climate change and the costs associated with the option are determined.</td>
</tr>
<tr>
<td>(6) compare and select the preferred option</td>
<td>this uses a series of incremental benefit : cost ratios (BCRs) to determine whether or not each option is the preferred one, assisted by a decision-tree that progressively removes options; this recognizes that as the probability of an event falls, the costs of reducing the risk associated with that event tend to increase more rapidly than the damages decrease; thus, as the standard of protection increases (i.e. The probability of a flood of a given magnitude falls) the required BCR increases.</td>
</tr>
<tr>
<td>(7) complete appraisal report</td>
<td>this assesses the appraisal against appraisal guidelines, but also provides for evaluation of a chosen option post-implementation.</td>
</tr>
<tr>
<td>(8) monitor, evaluate and feedback</td>
<td></td>
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the analyses of historical data, whether explicitly using the statistical method or implicitly through their parametrization of ReFH, they explicitly tie flood event history to the representation of the future, and we return to how the future is represented below. FEH also constrains the range of interventions that might be adopted. For instance, while it allows for exploration of the effects of a very small number of large upstream storage reservoirs, it is much harder to use FEH-based methods to look at a larger number of smaller interventions.

For hydraulic analyses, it is necessary to transform the flow estimates from the FEH methodology into a time-dependent series of water levels for estimation of inundation extent. This practice has two elements: (i) transformation of flow in the river channel into water levels, and their variation through time; and (ii) determination of the spatial extent of inundation that results. Although
the latter process is strictly two-dimensional, most analyses to date use one-dimensional treatments that do (i) and (ii) simultaneously, employing one of the two most widely used models in the UK at present, ISIS and HEC-RAS, as assessed by the EA [21]. In the simplest of situations, the river cross section is simply extended laterally to include the floodplain and the time-dependent flow applied to the extended sections. In more complex situations, the floodplain may be divided into a series of connecting storage cells, with water allowed to flow between them according to water level heights. In the most complex case, the river channel flow is modelled in one dimension and used as a boundary condition for a two-dimensional treatment using a model such as TUFLOW. As with FEH, the kinds of interventions that follow from having a working ISIS or HEC-RAS model are restricted.

5. Accounting, analysis and management

The above description shows how central to flood risk management is the analysis of the probabilities and consequences of flooding and its expression in monetary terms, a form of accounting. The end point of the analysis of risk is the provision of information that allows management decisions to be made, shaped by the financial outcome of the options assessed. However, both Defra policy and EA operational guidelines show that rather than risk analysis simply informing risk management, the management itself takes on an important role in determining the analysis that is undertaken and the suite of practices associated with this analysis.

First, flood events are ‘intermittent, variable, highly uncertain and sometimes extreme natural phenomena’ [17, p. 20]. Generally, it is assumed that larger events are less frequent and that larger events cause more damages but cost proportionately more in terms of delivering protection. The extent to which this is the case depends on the relationship between frequency, magnitude and consequence and this is commonly expressed in financial terms as the damages resulting from events of different probability, a ‘loss-probability curve’, which if the probability is set with respect to an annual likelihood of occurrence, yields the average annual damage (AAD) estimate when integrated [19]. The AAD estimate can then be used to prioritize options in a given geographical location and to prioritize those locations meriting investment. The form of the curve is continuous but may have sudden changes in gradient as a result of thresholds in the inundation process and so the EA [19, p. 235] gives a steer as to the probabilities that should be considered in populating the curve while also noting that the modeller will need to exert discretion in making sure the curve is sampled and so represented properly. Second, while the probabilities of events can be determined over any possible time scale, in theory, the risk analysis requires a decision as to the length of time, the time horizon, over which costs and benefits are compared, the design event that matters. This is set by Defra’s [17] interpretation of the lifetime of typical flood defence assets: 100 years.

Third, as described above, determination of the probabilities of events of different magnitude for a given location grounds flood risk management in a series of scientific practices associated with the measurement and analysis of river flows as well as simulation methodologies. In particular, it makes analysis dependent upon historical information because how often an event has happened in the past
is the basis for estimating the probability of it happening in the future: the past becomes central to the ways in which possible futures are framed. Likewise, data are required to estimate the consequences of events of different magnitudes. The latter depend upon both what is exposed to an event, something that changes with event magnitude, and the vulnerability of those elements exposed.

Fourth, as the concern is with establishing the costs and benefits of interventions over many decades, it is not possible to assume that either probabilities or consequences are statistically stationary, describable by a fixed statistical distribution that can be readily sampled. There is, therefore, the possibility that the future represents a departure from what we know from the past and so additional guidance is provided by the EA [19] in response to a steer from Defra [17] and we explore this guidance below.

These observations provide examples of how the nature of the accounting process, upon which risk management is based, frames the way that risk is to be analysed. Much of this follows from the fact that risk analysis is distributed across many scientific consultants, both individuals within companies and companies themselves. In order to secure the objective performance of flood risk management at the national level scale, and with respect to all of the other functions of government, those practices pursued in risk analysis have to become constrained. In the following section, we extend our evidence to consider those practices actually pursued by scientists in performing risk analysis and we do this by focusing upon two elements of accounting revealed by a series of interviews with consultants in the flood risk analysis field: (i) accounting for history and (ii) accounting for the future.

### 6. Accounting for flood history

Interviews with scientists undertaking flood risk analysis revealed the critical role played by historical flood events in informing the way the future is constructed; and that the data that these events provided were both formal (those recorded by instruments or remote sensing) and informal (such as personal recollections of inundation during events):

> you obviously have a system of gauges which are recording rainfall and flow around the country. And we would use those to calibrate the hydrological model ... Similarly you have a whole raft of other sorts of data, verging from the completely anecdotal: 'my kitchen flooded to six inches deep on this day', to, if you are lucky, some aerial photography that shows the extent of flooding during an event. And again we would attempt to use that to calibrate or verify the model's performance. When we don't have that data the level of uncertainty significantly increases because you are basing it entirely on the physical assumptions of the model.

[Consultant 3]

These historical events are important because the software packages contain a range of processes and parameters that are not always measurable or where the values that they must take are effective in that they must also represent processes excluded from representation explicitly in the software package. For instance, Lane [23] describes how friction values are ‘effective’ in one-dimensional
models like ISIS and HEC-RAS because they must also represent energy losses associated with secondary circulation and turbulence. Parameters like friction are valuable to the modeller because they are a means of making their model work (hence ‘effective’), of forcing empirical adequacy [14] through parameter adjustment to make model predictions fit historical events. Such is the reliance upon events to make models work that one interviewee advocated waiting for events to happen before embarking upon the modelling process:

There wasn’t enough calibration data, for example, that gauging records don’t exist, and the sensible thing now is to wait five years and take some records before you do the job... 

[Consultant 2]

For this consultant, a flood event is a form of ‘creative destruction’ [24], a future opportunity to make a model work. However, interviews also revealed substantial concerns regarding not only the practice of making a model perform to historical events, but also precisely what the performance should look like: uncertainties over the data representing those events. First, uncertainties regarding data reliability were raised:

the quality... it is sometimes difficult to know what the quality is because you are not out there taking the survey flows, you haven’t looked at, you have got what you got basically. You have got data at a gauging station but how good that is you don’t know sometimes. But yeah, a model is just as good as the data you put in is the old saying again.

[Consultant 1]

Second, there was a tension between the performative practices of modellers and the accounting practices being framed by Defra policy and EA guidance, especially the 100 year framework. Most UK flood records are only four or five decades long which means some form of extrapolation is required except in the rare case where longer records are available:

When we worked on the River Severn, that was the real exception, because it is the longest river in England and Wales, some of the gauges had records going back up more than 100 years, and that was very good, so you can be a lot more confident in your statistical analysis of the various flows, that you are getting near statistically what you might expect. But then the climate is changing, or maybe it is not. And things, the weather depends on obviously random events, but I don’t know I am not a meteorologist, but it is not predictable. All you can say is—well on the basis of what has gone before, the approximate estimate, lots of plus or minuses, is something like, around, it is not an exact science by any means.

[Consultant 2]

However, models that have been made to perform on one set of return periods may not perform over longer return periods:

So most sewer models are calibrated against a short term sewer flow survey of maybe eight weeks typically, in which you would hope to capture three minor storm events. But, unfortunately what we see is the occasional time when we do capture in a flow survey, a major storm event, the runoff can be completely different to the minor events, so trying to have a model calibrated against there very minor storm events, can be quite a big risk, when you then run it with a 30 year or 100 year design storm. Because it can be quite unrealistic, what flows you generate.

[Consultant 1]
Of particular concern was the effects of flow variability upon the estimation of the 100 year return period flows:

I mean quite often we have to model return periods, I think these days, we haven’t really got a clue what return period flow is. We used to think we did, there were some stability in the data, but in recent years there has been such variability, I think it is anyone’s guess as to what a 100 year flow is these days. And I know from trying to do it many years ago, actually measuring flows, is very far from perfect.

[Consultant 5]

Third, data were sometimes reported as problematic, expressed here as causing difficulties for model forcing where their testimony was unreliable:

A job we did not so long ago, we couldn’t get one of the records to fit at all, our model kept showing, I can’t remember what is was, but something like our levels were half a metre lower than the recorded levels, and we couldn’t get it up there at all. And after going round and round for months, it was decided that someone better go out and actually check the recorded level of this gauging station, and it was out by half a metre, so we had been trying to fix, fiddle, change things to match this data which was in fact wrong itself.

[Consultant 1]

Indeed, in accounting for historical events consultants acknowledged that they had to subvert the normal presumption that a model’s predictions should be subsumed to empirical testing:

ideally you would know what your flow is, you would know what your levels are downstream. You put that in your model and you can change the model to produce the levels. But if you are not sure about your flow, well you could be changing your model for the wrong flow. Or equally you could do it the other way round and which I might have to do in X, use my model to say ‘well, we know it overtopped here, and it didn’t overtop there, so the flow must be between these levels’, and assume the model is correct, which is the opposite way round to what is normally done. Given that it is a model that has been around for a long time, it has been calibrated against smaller events, that might be what I end up doing.

[Consultant 11]

This consultant also commented on how what appear to be ‘data’ can actually be ‘model estimates’. For instance, river flows (as data) are hard to measure directly although this is being changed by new technologies. Thus, estimates of river flow are made from more easily measured water levels using models, some that are simple empirical calibrations between instances of measured flow and water level, applied to continuous records of water level, others that might have more of a physical basis.

The role of historical data takes on additional importance in relation to design events. As recorded events rarely map onto the specific return periods or probabilities required for analysis, design events have to be defined in order to populate the probability–loss curves and ADD estimates described above. Such events are ultimately fictions in that they do not appear in the historical record, but are needed critically to create the continuous representation of flood history necessary for the ADD estimation. These fictions require creativity. On the one hand, a hydrological analysis may have allowed identification of the magnitude of the flow peak associated with a given return period. But, on the other, specifying
a design event requires estimation of the time-dependent rise of the hydrograph to that peak, and its subsequent fall; the full hydrograph. The hydrograph shape influences the volume of the flood which, in many cases, also influences the subsequent inundation extent and flood exposure. As with the determination of the probability of flows of different magnitude, specification of the design flow requires the consultant to draw explicitly on historical data to set these additional parameters.

The above account shows how the practice of flood risk modelling involves accounting for the history of past flood events. It is by accounting for this history that past flood events become encoded, materially, in investments in flood protection and hence the form that future flooding takes. This encoding has two elements. First, models are made to perform past events. Delaying application of a model was even advocated to be necessary as, without an event, it was not clear what the performance should look like. Second, history has to be rewritten because the histories of flood events (e.g. the return periods of the peak flood flows experienced) do not necessarily map onto the framework for evaluating interventions set by the wider accounting process. The response of consultants to this is to introduce additional analyses of historical events but this increases substantially the range of possibilities for what a flood with a given return period might look like. Both of these accounting practices are subject to a particular reservation frequently raised by consultants: uncertainties in the data available to them or what the histories should look like. Here, there was a tension revealed between the need to believe the past, in order to make the models work, and the possibility that this necessary empirical evidence might actually be incorrect. If there is no reliable history to account for, there is no means of rationalizing the multiplicity of possible forms that model predictions might take. Even before the future is modelled, there are uncertainties emerging about the ‘evidence base’ required for a historical account.

7. Accounting for the future

If the past is, in statistical terms, a reliable indication of the future, then the past becomes the means by which the future can be accounted for. However, in accounting for the future, the possibility that the future might deviate from the past is recognized. Defra [17, p. 20], in its overarching instructions on the implementation of HM Treasury’s guidance, notes that: ‘Operating authorities should make assessments of probability from past events and project forward using best available information on climate change and other uncertainties.’ Two important strands of evidence show what kind of deviance the future is expected to take.

The first strand of evidence is a perceived dominance of climate change in shaping the translation of the past into the future (e.g. [17, p. 20]). The means by which this is done is through a ‘climate change supporting document’ linked directly to flood risk appraisal guidance [19, p. 31] and also referred to by Defra [17]. This document was issued by Defra in 2006 as a supplementary note to previous flood risk management appraisal guidance. The 2006 note requires that peak river flows ‘for larger catchments’ [25, tables 2 and 4] should be scaled upwards by +20 per cent to the 2080s but that for ‘small catchments and
urban/local drainage sites’ [25, p. 3] less than 5 km² in area where direct rainfall is used in hydrological modelling, peak rainfall intensity should be scaled by +10 per cent for 2025–2055, +20 per cent for 2055–2085 and +30 per cent for 2085–2115. These changes do not change the frequency of flooding explicitly but, by scaling the peak flow for all flows in the historical record, have the effect of making a flow with a probability under current climate more frequent as a result of future climate change. Consultants recognized the importance of climate change to future flood risk, for example:

Interviewer: ‘What do you see as the major challenges in modelling today?’

Consultant 6: ‘Climate change sounds like the obvious one. Recent guidance from Defra—from what sort of parameter inputs to factor up rainfall intensities or river flows, in some areas, it makes it a really really significant impact on the type of flood hazard or flood risk.’

Consultants routinely referred to the guidance as the +20 per cent rule, for example:

And also there is a big focus on the uncertainty of climate change, and so that tends to get slapped on to the end of a flood estimate and you would add on 20% for climate change just in case. And I think there is a... that tends to be what people are most worried about. I was going to say you get a flood estimate and then you make it higher just in case.

[Consultant 9b]

[the] government’s planning guidance for flood risk, and that says...over the next 100 years river flows, in very broad terms, may increase by 20%. So we put on 20% and see what happens, how much more flooding that causes.

[Consultant 2]

Most interestingly, all other elements of the risk analysis, and notably consequence, tend to be assumed to be stationary over the 100 year time period. This is reflected in application to particular catchments. For instance, the River Ouse (Sussex) Catchment Flood Management Plan [26] reports a sensitivity analysis of the likely changes in future flood risk arising from climate change (set using the +20% rule), urban development and land management and concluded that urban development and land management have very little influence on future flood risk. However, closer inspection of the report reveals the reason for this conclusion: ‘Our assessment does not include the impact of any additional building or infrastructure being placed in the floodplain in the future. It is assumed that this will be prevented by appropriate development control, however if it were to occur, the cost of flood damage could increase significantly, depending on the nature of the development (economic and social value) and the depth and frequency of flooding’ [26, p. 106]. The conclusion is not that urban development is unimportant but rather that regulation is going to prevent it from happening in areas where it might increase consequence and hence risk. Separate ‘futures’ work [27] challenges this assumption because the strength and nature of regulation depends upon the kind of resultant political–economic–social future. Under two of the future scenarios Evans et al. [27] considered (world markets; national enterprise), urban development had the dual effect of
increasing both flood probability and flood consequence, the latter associated partly with unregulated development of floodplains linked to weak planning controls. Consultants emphasized the difficulty of handling non-stationarity in consequence:

I guess the other uncertainty, because we are looking 50 to 100 years time. All our data is based on the urban areas and the properties that are there now, and everything that is there now, and then looking at the flood events in a hundred years time, we don’t really know what is going to be there, so it is all based on current data. And the best guesstimates, because all the planning documents only look at the next 20 years ahead, they don’t look at 100 years ahead, where they think that developments are going to be.

[Consultant 4]

They also made wider reference to the fact that there will be development in floodplain areas, and associated changes in consequence, given existing development provision in statutory plans:

Thames Barrier and something called Thames Estuary 2100 which is all about trying to look at the next 100 years and extend the life of both the Thames Barrier but also the raised defences on either side of the Thames to take into account climate change impacts. And that is quite interesting because it is, in terms of risk exposure, it is by far the biggest risk in the UK. It is an area that could suffer over the next 100 years, so we do a lot of work.

[Consultant 6]

What is going on here is similar to Cartwright’s [12] notion of *ceteris paribus* laws, where laws can only hold when certain codifiers are attached to them. Here, the difficulties of predicting changes in consequence in the future are overcome by restricting practice to consideration of a subset of what might be non-stationary. This restriction is achieved through introducing a set of codifiers that make demands of other practices, in this case regulatory activities that constrain changes in consequence. The faith that regulation can make the future realized as climate change is interesting for two reasons. First, consequence is not just about the physical location of property but, as Evans *et al.* [27] emphasize, a whole series of other factors that are beyond regulation, such as the way we live in those properties (e.g. basement conversions; furnishings and fittings; changing dependence on critical infrastructure). Second, history shows that regulation is markedly ineffective in regulating the floodplain development of changing consequence. After the worst floods of the twentieth century (March 1947), the UK’s government described for the example of West Bridgford, a suburb of Nottingham on the River Trent, how by 1947 it had come to occupy ‘the natural washland of the river, in which our forefathers knew by experience not to build...’ [28, pp. 70–71]; ‘All that can be done is to ensure that such mistakes are not duplicated in the future...Contact is being made throughout the country between the river authorities and the town-and-country planning authorities to ensure that no more building takes place on land that is bound to be inundated whenever heavy floods occur’ [28, p. 85]. Development continued on the Trent floodplain after 1947 and now almost all of the 1:100 year inundated floodplain is occupied. This example shows a differential translation of the past into the future. While the determination of probabilities using past events is allowed, and their scaling for the disjuncture of the future from the past associated
Table 2. Predicted changes in the magnitude of peak flows for different return periods by the 2080s, from Reynard et al. [29,31] for the rivers Severn and Thames.

<table>
<thead>
<tr>
<th>return period</th>
<th>study date</th>
<th>Severn</th>
<th>Thames</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>-5.0(^b)</td>
<td>16.3</td>
<td>-5.5</td>
</tr>
<tr>
<td>10</td>
<td>6.2(^a)</td>
<td>6.6</td>
<td>-4.8</td>
</tr>
<tr>
<td>20</td>
<td>16.5(^c)</td>
<td>17.9</td>
<td>-3.1</td>
</tr>
<tr>
<td>50</td>
<td>23.7(^d)</td>
<td>25.0</td>
<td>-2.6</td>
</tr>
<tr>
<td></td>
<td>-12.1(^e)</td>
<td>-15.8</td>
<td>-19.4</td>
</tr>
</tbody>
</table>

\(^a\) Monthly percentage rainfall change to each rainfall in baseline data.
\(^b\) Changes in number of rain days in a month from baseline.
\(^c\) Monthly percentage rainfall changes added to extreme rainfalls only.
\(^d\) As per footnote a but with a 15% increase in urbanization.
\(^e\) UKCIP02 scenarios.

with climate change strongly advocated, other kinds of historical understanding, such as the dramatic inability to regulate floodplain development, are not. Thus, the kinds of futures imagined are distinctly hybrid: nature is allowed to become statistically unstable; but society has to be regulated and stabilized so as to make it conform to those futures that are allowed to become unstable, albeit only in certain ways.

The second strand of evidence focuses upon where the +20 per cent rule comes from. The Defra [25] document that confirmed adoption of the +20 per cent rule can be traced back to Reynard et al. [29] which reports work commissioned by the joint Defra/EA Flood and Coastal Erosion Risk Management research and development programme. In turn, this pointed to an earlier research and development programme [30,31]. Table 2 shows data from Reynard et al. [29,31] for the two catchments common to both studies. Comparison of these two studies is not entirely meaningful in a detailed sense as shown by the footnotes of table 2. Between the two research and development studies: (i) global climate modelling predictions change, notably in terms of introducing a number of emissions scenarios by 2005 and also a finer model resolution (50 x 50 km rather than approx. 280 x 262 km); (ii) global climate models provide monthly rainfall estimates, requiring downscaling, methods that have also changed; and (iii) the treatments of other elements of the system have changed. For instance, Reynard et al. [31] included some land use change impacts, such as urbanization; but none are included in [29]. However, the comparison is instructive because the inference by Defra, the +20 per cent requirement to scale peak flows, is the same from both studies. A number of points emerge. The 2001 data show relatively similar responses for each catchment in terms of predicted changes in
peak flow, but a very strong dependence upon how the rainfall is downscaled. The latter is based upon auxiliary assumptions about what future climate changes might look like in addition to those contained within global climate models. By 2005, Reynard et al. [29] were able to use UKCIP02 predictions with a much finer spatial resolution, predictions for different emission scenarios (table 2) and a single rainfall downscaling method that combined elements of different downscaling treatments. Table 2 shows that by 2005, the differences between the two catchments were now substantial, with all of the Severn’s peak flows forecast to decline and those of the Thames not showing much change except for the case of the Regional Climate Model simulations. The relationship between peak flow change and return period depends on emissions scenario for both catchments. Reynard et al. [29] also present estimates for eight other catchments suggesting substantial variation between catchments in the response of peak flows by the 2080s, but with the +20 per cent figure only exceeded for one catchment using the default UKCIP02 methods. When natural variability was added into the hydrological series, this rose to three catchments.

With such spatial variation, and results that are not entirely conclusive regarding future climate change effects on river flows (e.g. variation with emissions scenario), three responses followed. First, Reynard et al. [29, p. 61] concluded ‘...the impacts of climate change in flood frequency in the study catchments, under the selected scenarios, [are] considerably lower than those previously determined’ (i.e. in [30,31]). Second, Reynard et al. [29, p. 61] justified retention of the +20 per cent scaling in terms of precaution: ‘...under these scenarios, the current 20% sensitivity band appears appropriate as a precautionary response to the uncertainty of future climate change impacts on flood flows.’ They also noted [29, p. 61] that ‘To a very large degree this conclusion is determined by the dry and warm nature of the Hadley Centre model used to generate all the scenarios and using other GCMs will undoubtedly produce different results.’ Third, they flag the issue that geographical location may be critical not only in creating spatial variability in climate change but also the response of river catchments to those changes. They noted [29, p. 62] that ‘The results from this project are finding a higher degree of spatial variability and catchment response than was initially anticipated.’ Exploration of the spatial variation in response is then reported in November of 2009 [32], shortly before the EA’s appraisal guidelines that refer back to the +20 per cent criterion were published in March 2010. This explicitly identified different types of catchment response (e.g. damped, sensitive, neutral) and estimated peak flow changes for each return period for each catchment response. The result is a methodology that allows for catchment specific definition of the necessary climate change scaling factor that takes into account uncertainties arising from a range of factors, including emissions scenario, level of information available in a catchment, etc.

A number of points emerge from this second strand of evidence. First, current predictions of future peak river flow changes over the next 100 years due to climate change have been markedly unstable in response to the development of research methodologies. This development is not a consequence of classical ‘belief revision’ (e.g. [33]) in which new empirical evidence forces theoretical change, but rather the progressive development of simulation models, as mathematically coded sets of theories, themselves. Consultants recognized that this was going to
happen and that their modelling approach needed to adjust to this. In response to a discussion regarding climate change predictions, one consultant noted:

\[\ldots\text{it is just we are in uncharted territory. I don’t believe any—all I believe is that it is actually changing. I just don’t believe any of the predictions, because any of the predictions from here to there, so constantly re-evaluate where we are and put our models in a format where you can make those rapid changes. So if you want to fundamentally change the hydrology you can do it in a few days, not a few months. Because we may be in a position where we have to start thinking quickly on our feet.}\]

[Consultant 3]

Here, the model is being described as a means of speeding up time, by bringing the future into the present.

Second, interventions are discrete acts and, in this case, have to be based upon the future as it has been made knowable now. The predicted flow changes have had to become settled in order for a cost–benefit framework to be applied and in turn, these take on a material manifestation in terms of where investment in flood risk management happens, and what form it takes. Third, the consequences of a change in the +20 per cent rule, at any stage, would be to create a spatial variation in the standard of protection as a result of the historical legacy of previous interventions.

8. Accounting for practice

The implication of adoption of the +20 per cent rule is the stabilization of a uniform approach to accounting for the future. It points to a third element of flood risk management practice which involves accounting for those practicing flood risk management. Landstrom et al. [20] report both interviews and ethnographic work that describes the ways in which flood risk management is practiced in consultancy in the UK. This revealed a process of standardization, based upon the use of a restricted set of software packages and the finite number of consultants retained by the EA in Framework Agreements. Consultants recognized that this had a major impact upon their practice: ‘Models determine what is modelled’ because different models represent different elements of the flood system;

\[\text{process representation say if you block all of the outpours from the surface water drainage system, and suddenly you will have, quite removed from the river environment, you will have surface water flooding, because there is an interaction between those two environments, so you will have flooding there as well. But of course within a fluvial model that we have predominantly talked about here in terms of ISIS and TUFLOW and whatever else, it wouldn’t necessarily take that into account, because you are not explicitly representing those flow paths. So sometimes that can be where process representation can cause problems.}\]

[Consultant 6]

The adoption of particular software packages causes flood risk to be constructed in particular ways:

\[\text{And one of the big problems of course, which has been brought out by what has happened in the last few months in this country, is that their flood maps only show their estimates of flooding of water which comes out of rivers because the rivers are overfull. It doesn’t show}\]
the flooding caused by water trying to get into the rivers because it rains too much. And a lot of the flooding certainly in places like Hull and part of what happened in Sheffield this summer [2007], was not water coming out of the rivers. In Hull it wasn’t at all. It was water that fell on the ground and couldn’t get into the rivers. And then those maps don’t show that.

[Consultant 2]

This construction extended to the ways in which particular modellers used particular software packages:

But, in practice I am still sure today that if you take even six experienced hydrologists and you give them the same software and the same problem and you ask them to come back, something very simple, a 100 year return period flood estimate. Same software, same conditions, they would all come back with a different answer, the concerning thing is that the answer isn’t going to be very very close…

[Consultant 6]

A key theme emerges in the tension between the need for a modeller to use their skills to intervene in a process that is, otherwise, highly dependent upon technologically driven automation and the attractions of progressively more standardized procedures:

...when you get the outlines, sort of automatically produced from your water levels... the sort of, the not smooth, neat and continuous— we have to draw the smooth neat and continuous ones round it, and in doing that you make a judgement like if you have got the river here, and it comes out a bit in a big puddle there, well this bit of dry bit that was showing up on from the Lidar data, is that a real bit of high ground that you could rely on to prevent the water getting over, or is there actually some way the water can get over?

[Consultant 11]

At the same time, the progressive standardization of models and the ways in which they are used is appealing because it reduces possible differences between model outputs associated with variations in modelling practice:

Strengths are that you know you... generally speaking if you have two hydrologists using the FEH on a given catchment, theoretically they would both come up with the same answer. Previously using the FSR there was significantly more interpretation in there, which meant if you asked two people you would probably get three answers.

[Consultant 3]

This process of standardization is important as it represents a response to the creativity embodied in the idea that modellers have to make their models perform against past events; a response to the need for supposedly objective comparisons of risk allowed by cost–benefit analysis; one that is independent of those who are doing the comparisons. However, it also shows how this standardization frames risk in very particular ways. The focus of practice upon a restricted set of software packages (FEH; ISIS/HEC-RAS) means that certain sorts of flood events become represented in accounts of flood risk. What unsettles these practices is events which place water in parts of the landscape which the models suggest are not at risk. In the case of the 2007 event referred to by Consultant 2, a wholesale reorganization of flood responsibilities followed [34] and where the landscape of

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risk as constructed by FEH and ISIS/HEC-RAS is being actively transformed to include a new suite of software packages capable of representing other elements of flood risk.

9. Conclusion: a precession of simulacra

The evidence we present above shows how interventions in hazardscapes are shaped by a suite of practices that are not characterized simply by the conventions of scientific analysis but are framed by the very management activities that they seek to inform. The need for this framing comes partly from the multitude of possibilities by which the future might be constructed but also the need to ‘account’, to enable risk to become expressible in monetary terms such that the costs of making an intervention can be judged against the benefits that society is likely to accrue in the future. Central to this accounting process is numerical simulation and within the framework of this simulation a suite of practices has developed driven by a cascade of financial requirements regarding the cost–benefit performance of government interventions in general, and risk reducing measures in particular. It feeds into the policy that frames flood risk management [17] and then those guidelines used to operationalize that management [19]. In turn, this creates the context in which risk analysis has to be undertaken, and defines the kinds of futures (e.g. how far into the future; the extent of disjuncture between the past and the future) that must be considered. The suite of practices involved use particular software packages to assess flood risk probabilities (i.e. the likelihood of a particular location on the flood plain being inundated to a particular depth). These tools were recognized by consultants as constructing flood risk in particular ways, as closing the analysis down, and hence producing particular kinds of interventions. Flood events played an important role in unsettling this suite of practices by drawing attention to elements of flood risk excluded from or overlooked by a particular analysis. The suite of practices was also shown to be performative in that models had to be forced to account for historical flood events. This is not simply a matter of providing some kind of ‘hindcast’ analysis of model performance so as to justify use of a model in a futures analysis, something that might be argued prevents numerical simulation models from being the kind of ‘pseudoscience’ described in the introduction. Rather, it involves actively making models perform because they contain poorly known processes and parameters. A lack of recorded historical events was even advocated as a rationale for delaying a flood risk analysis. Thus, the past becomes written into the future through a suite of modelling practices grounded in the present.

The propagation of the past into the future is critically dependent upon an assumed statistical stability in river flows. There was awareness that this assumption did not hold and this was primarily reflected in the recognition that climate change would cause the future to look very different to the past. As a result of this, consultants were required to follow government guidance, manifest as a +20 per cent upscaling of estimated peak river flows for the 2080s. In the face of some scepticism over the reliability of these scalings, if not over climate change itself, consultants felt that their models had to be eminently responsive: i.e. provisional but adjustable in the face of changing understanding, able to mutate through time. The provisional qualifications of the model and of the
science underpinning the +20 per cent upscaling contrast markedly with the stability associated with the decision to intervene. But it also revealed a deeper set of codifiers that allowed the provisionality and instability of one element of the future, climate change, to dominate in its representation over other, perhaps equally provisional and unstable, elements of the future.

Stirling [35] provides a means of understanding this state, by introducing a distinction between degrees of likelihood (essentially probabilities) and possible outcomes (essentially consequences). His analysis shows that risk management is underpinned by an analysis that simultaneously removes the ambiguity regarding outcomes and the uncertainty regarding likelihoods such that both become unproblematic. Our evidence shows that scientific analysis is strongly entwined with both policy (e.g. the primary emphasis given to cost–benefit analysis) and management (e.g. operational guidelines used to define options appraisal). Policy and management provide closure for analysis by removing ambiguity and making an apparently objective tool (cost–benefit analysis) operational in practice. The uncertainty of climate change effects is rendered apparently unproblematic through the systematic adoption of a simple upscaling rule. Similarly, the ambiguities of consequence (e.g. which tangibles, which non-tangibles, to consider) are closed through explicitly requiring the analysis to be undertaken as part of a financial accounting process; and through introduction of additional codifiers (e.g. that regulation will prevent floodplain development) that stabilize the otherwise unstable. In other words, in order to make numerical simulation of the future an effective basis for intervention, and to develop a suite of practices that can uniformly and objectively justify this intervention, the world has to be laid out [24] in such a way that its dynamic, the future, becomes fixed and simulatable. The effectiveness of the material expressions that follow from these futures (e.g. a decision to intervene or not to intervene) becomes contingently dependent not only on the analysis that underpins them, but the codifiers that have been required to close the problem and the associated suite of practices that supports them. For such interventions to be effective, the future has to come to mimic the numerical simulations, and the codifiers upon which they are based, and there has to be what Baudrillard [36] calls a ‘precession of the simulacra’. Here, the flood event, both historically and in an imagined future, has become the simulation and the simulation has become the flood; the two becoming conjoined in their material expression in the landscape. In order for this material expression to remain effective, the management of risk becomes a continuous battle to keep the future on the course set out by the simulation because the future is calculated to be sustainable only if it is made to look like what the simulation imagines it to be.

Lord Rees argued in his Reith lectures that ‘as I said earlier about science advice in general—it’s crucial to keep “clear water” between the science on the one hand, and the policy response on the other. Risk assessment should be separate from risk management.’ In many senses, and returning to Lord Rees’s opening quote, our account shows that what separates flood risk estimation from astrology has less to do with the separation of risk assessment and management than with the burden of social accountability attached to the risk management regimes of which the calculation of risk is inextricably a part. Such accountability requires an openness about the scientific and policy procedures that make flood risk estimations more (or less) reliable to those we entrust.
to produce and act upon them such that, unlike astrology, they can be put to the test of public interrogation, not least by those who have to live with their consequences.

This work was funded by grant RES-227-250-018 from the Rural Economy and Land Use programme of three UK research councils (BBSRC, ESRC and NERC) and Defra. We are particularly grateful to the many consultants who gave up their time to be interviewed during the project.

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