Managing coastal flood risk to residential properties in England: integrating spatial planning, engineering and insurance

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Abstract

Flooding is the most damaging natural hazard in England today. Coastal flood risk management aims to reduce the impacts of coastal flooding through adaptation measures including spatial planning, engineered hard and soft interventions, and insurance. Yet there are few reviews which collectively assess these measures. This paper aims to characterise and evaluate coastal flood risk management policy in England across planning, engineering and insurance approaches, focusing on their ability to manage risk to residential properties. An analysis of the literature and government reports reveals that together these management approaches address the different dimensions of flood risk. Nonetheless, the three approaches are legislated and regulated in relative isolation, and in their current formation have contrary implications for existing and future residential developments. There is also further scope to increase the resilience of planning, defence and insurance to social and environmental uncertainties in financing, governance and climate change. We recommend that future research and strategies in coastal flood risk management give greater consideration to multiple flood risk management approaches in conjunction, continuing to expand the integration between planning, engineering and insurance approaches.

Keywords

Coastal flood risk management, resilience, insurance, spatial planning, flood protection engineering

1. Introduction

Coastal flooding is a major risk to England (Cabinet Office 2010; Cabinet Office 2017) with distinct drivers as compared to other flood types. Coastal flooding occurs through a combination of extreme water levels – due to storm surge, high tide and wave action – interacting with England's existing coastal defences to cause the overflowing, overtopping or breaching of the shoreline and defences (Zong and Tooley 2003; Vitousek et al. 2017). Despite centuries of adaptation, coastal flooding continues to pose a significant risk to England (French 2001); a brief overview of select events and policy is presented in Figure 1.

Following years of poor maintenance and underinvestment in sea defences combined with development on the coast, the 1953 East Coast floods killed 307 people along England's east coast and nineteen in Scotland, damaged 24,000 houses, and inundated 64,750 hectares of farm land with sea water (Summers 1978; Met Office 2016; Haigh et al. 2015). This event was pivotal in transforming coastal flood management in England, and a key driver for the launch of domestic property flood insurance, significant reinvestment in flood defences, and the creation of a nationwide flood warning system (Lumbroso and Vinet 2011; Penning-Rowsell 2015). Most coastal floods that have occurred since 1953 have been generated by moderate (as opposed to extreme) surges, combined with high spring tides (Haigh et al. 2016).

Whilst England has experienced severe coastal floods in the past century, there is potential for more frequent high impact events because of climate change effects on sea levels and continued population growth in coastal areas (de la Vega-Leinert and Nicholls 2008; Haigh et al. 2016). Coastal flood events such as these exemplify the high-impact low-frequency nature of this risk; coastal flood events remain difficult to reliably predict, with potentially catastrophic impacts if not effectively managed (Lee, Preston and Green 2012). Although significant coastal flood events are generally infrequent, the 1953 floods exemplify the potential impacts if we are not prepared. In the face of ongoing and future population and climate change, coastal adaptation through risk management will need to consider multiple diverging future scenarios, with uncertainties in flood causes, processes and consequences (Evans et al. 2004; Cheong et al. 2013; Sayers, Walsh and Dawson 2015).

Integrated flood risk management suggests a role for planning, engineering and insurance in the management process (Hall et al. 2003b; Evans et al. 2008; Russell et al. 2018), but both in policy and literature these approaches have not been recently analysed side-by-side with equal attention to review how they manage coastal flood risk. This paper reviews how contemporary spatial planning, engineering and insurance approaches to flood risk management are being employed to manage coastal flood risk to residential properties. The paper uses the governance context of England as an in-depth example of a country with a long history of coastal defences, as well as planning and insurance approaches to managing flood risk. Previous research on flood management assesses the role for engineering and planning interventions (Barrett 1992; Begg, Walker and Kuhlicke 2015; Ran and Nedovic-Budic 2016), but comparative work including insurance generally limits its role as a responsive flood loss and recovery approach (Arnell and Chatterton 2007), rather than also considering its pre-flood event risk management attributes. We build on recent reports that provide a vision of flood and coastal risk management for the twenty-first century (Future Foresight Flooding, Managing the Coast in a Changing Climate, see Figure 1,), providing an analysis of coastal flood risk management across disciplines for residential properties in England.

Flood risk management is a prevailing adaptation paradigm for flooding in Europe today, and the flood risk management cycle encompasses protection, preparedness, emergency response, recovery and lessons learned, and prevention (Commission of the European Communities 2004; Cassel and Hinsberger 2017). In recent years, there has been increasing recognition and attention for the importance of effective emergency response. England has developed a network of tide gauges for research and emergency planning for coastal flooding and the Environment Agency (EA) has campaigned for households to subscribe to flood-warning systems. However, the focus of this review is on longer-term protection, preparedness and prevention elements of flood risk management, and not on the response and actions undertaken during flood events. Other research addresses the role of early warning systems and emergency response preparedness within flood management (Khatibi and Haywood 2002), and factors affecting the effectiveness of emergency preparedness (Goulter and Myska 1987; Kreibich et al. 2011).

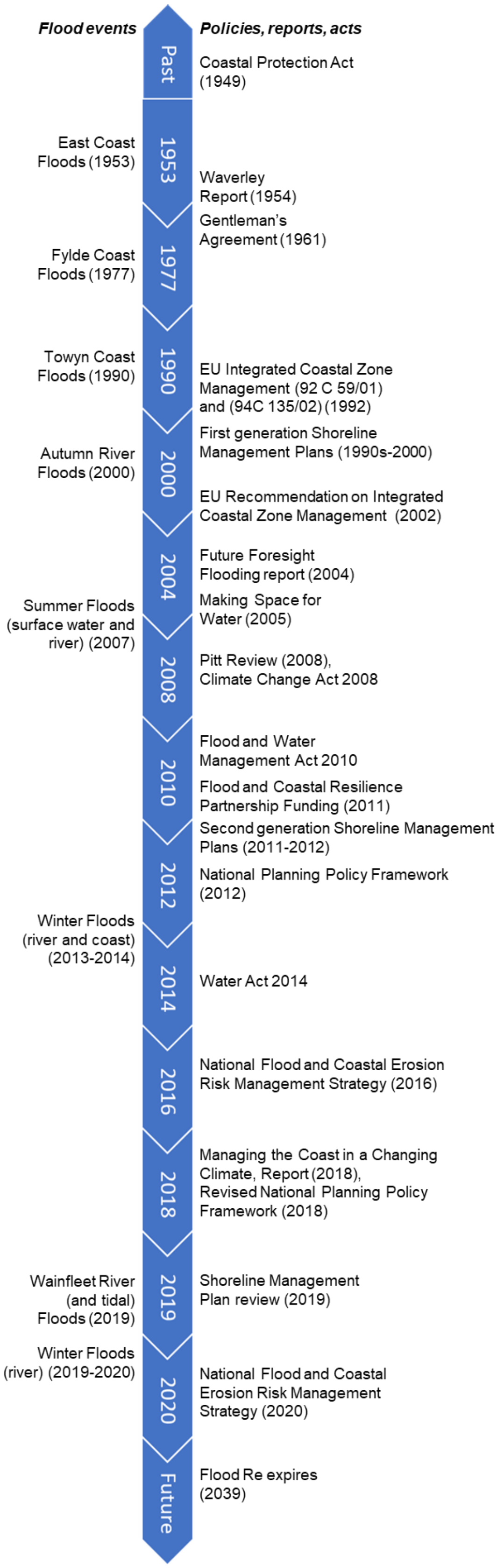

Fig. 1 Timeline for context, highlighting selected significant flood event and policy years in England since 1953.

First, we review how academic literature and national government policies define and propose coastal flood risk is managed for residential properties through spatial planning, engineering adaptation and insurance in England. Second, we analyse literature and policy for the strengths, weaknesses, opportunities and threats (SWOT) of the cost, timing, power, responsibility, acceptability, equity, and effectiveness in planning, engineering and insurance approaches to coastal flood risk management in England. The conclusion provides comment on the progress on coastal flood risk management in England since the Foresight Future Flooding Report (Evans et al. 2004), and opportunities for further progress.

2. Adapting to coastal flooding in England

This section presents an overview of the definitions and characteristics (policy, scale, application) of planning, engineering and insurance as coastal flood risk management in England. Contemporary coastal flood adaptation in England is overseen by Defra (Department for Environment, Food and Rural Affairs) and the EA, yet responsibility is also devolved to local government. Figure 2 outlines the governance structure of FRM in England, where flood risk falls under the responsibilities of Defra, but the EA is legally *the* English risk management authority (*Flood and Water Management Act 2010*), responsible for developing, maintaining, applying and monitoring a strategy for flood and coastal erosion risk management in England. The *Regional Flood and Coastal Committees (England and Wales) Regulations 2011* set out the establishment of committees for all of the English and Welsh coastline, from which the EA must obtain consent to carry out planned flood and coastal erosion risk management programmes. Certain aspects of flood and water management are devolved to the governments in Scotland, Wales and Northern Island, but the scope of this review is limited to England. While lead local flood authorities (LLFAs) are responsible for risk management strategies at the local level, this is specifically for surface runoff, groundwater and ordinary watercourses.

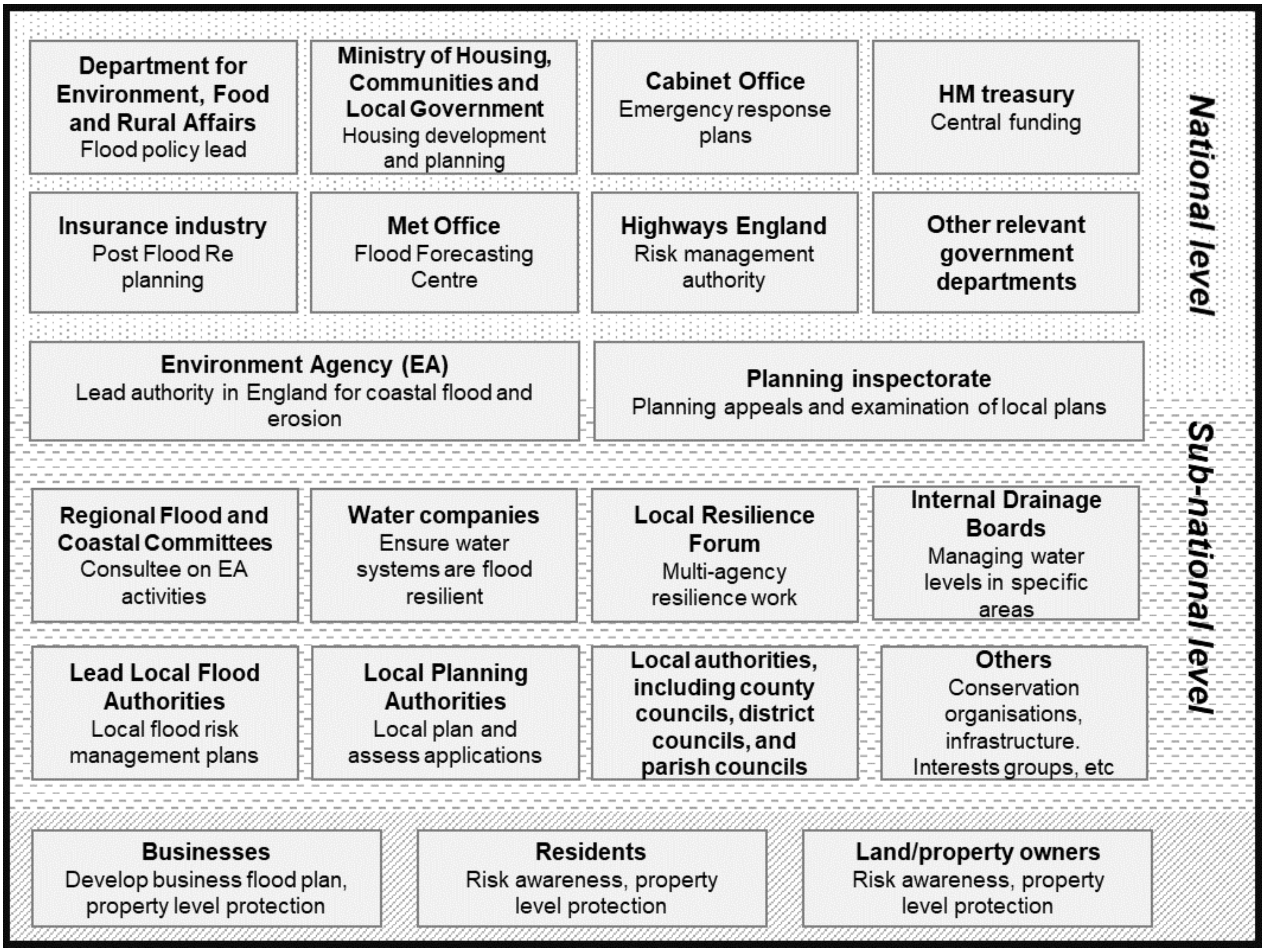

Fig 2. Administrative structure of flood risk management in England (adapted from Alexander et al. 2016, p13, and Russell et al. 2018, p44).

There is a national ambition to reduce flood risk: in 2016, the UK Government announced its intention to reduce flood risk in the coming 25 years, through further flood and coastal defences, improved understanding and mapping of extreme flooding, and testing key infrastructural and city resilience (Defra and Cabinet Office 2016). That reduction is also necessary if risk-reflective insurance prices are to be affordable in 2039 (ABI 2014), the ambition of the *Water Act 2014*. Further to this, as part of the most recent National Flood and Coastal Erosion Risk Management Strategy, the EA outlined collaboration between the insurance sector and risk management authorities to increase property level flood resilience measures in communities are greatest risk (EA 2020). Although flood risk management in England thus currently takes place at multiple scales, the main focus of this review is on national scale policy.

Spatial planning, engineering and insurance have evolved since the mid-twentieth century, and have been subject to repeated reviews and policy changes in this time.

Sections 2.1-2.3 outline the three approaches that dominate England's contemporary approach to manage floods, and their defining characteristics are summarised in Table 1.

Table 1 An overview of coastal flood adaptation approaches in England (references in text)

	Spatial planning	Engineering	Insurance
Definition	The policy and practice of the organisation of the intended purposes for land, incorporating flood knowledge of areas to shape development plans and planned purposes for that space – to manage flood risk.	The use of soft and hard physical interventions, to support, maintain or develop existing natural or human risk reducing features, applied to local to system scales – to manage flood risk.	Redistribution of the potential financial damages of flooding through the market. Can also be used to enable or discourage development in hazard areas, as well as to encourage property-level resilience – to manage flood risk.
Example	Developments planned in floodplains are reviewed by EA	Sea defences, dikes, beach nourishment, managed realignment	Flood insurance as a part of household insurance
Funding sources	Central government Local government	Central government (EA, Defra) Partnership funding from private and public sources Local levies	Central government Flood Re (levy and premiums) Reinsurance Household premiums
Spatial scale of policies	Local and national	Local, regional and national	National
Spatial scale of implementation	Local and national	Local and regional	Property-level
Temporal scale of implementation	Decades	Decades	Annual and decades
Key policies	Part 6 of the Housing and Planning Act 2016 National Planning Policy Framework 2012, 2018 Part 6 of the Localism Act 2011 Planning Act 2008 Making Space for Water 2004	National Flood Resilience Review 2016, 2020 Thames Estuary 2100, 2012 Flood and Coastal Resilience Partnership Funding 2011 *Flood and Water Management Act 2010* Making Space for Water 2004	*Water Act 2014*
Key players	HM Government Politicians, communities and other interest groups County and council planning authorities Developers and landowners Environment Agency	HM Government Defra Environment Agency Coastal industry Coastal communities and flood groups Regional Flood and Coastal Committees	Association of British Insurers FloodRe HM Government Insurance companies Households

2.1 Spatial planning

Spatial planning influences the nature of places and how they function (Harris and Pinoncely 2014). Planning describes the policy and practice of the organisation of the intended purposes for land; for flood risk management it incorporates flood knowledge of areas to shape development plans and planned purposes for that space. By directing land use decisions today to prevent unwise floodplain occupation or development, planning has the capacity to be applied for decadal solutions under scenarios of climatic and social change (Carter and Sherriff 2011). National legislation for spatial planning was established with the *Town and Country Planning Act* in 1947. Planning policy guidance for flooding informs authorities of how existing flood risk knowledge should be taken into account for the planning of developments. In the past, the MAFF Circular FD1/92 of 1992, stated that flood defences "should always be taken into account by local planning authorities" in development plans, and the National Rivers Authority a statutory consultee to consider the impacts of a development on its flood defences as well as flood risk (Department of Environment, MAFF and Welsh Office 1992). Today, the National Planning Policy Framework (NPPF) sets the national planning strategy for England (published in 2012 and 2018). With regard to flooding, it states that inappropriate development be avoided in areas at risk of flooding, but where necessary, made "safe" without increasing flood risk elsewhere (DCLG 2012b, p23).

Government remains a key player in spatial planning for flood risk management. Much of planning policy is set nationally (see Table 1), but national policy also grants significant flexibility and power to local authorities. Locally there are often housing and economic pressures which are being met by allowing development on floodplains (Porter and Demeritt 2012), and thus this decision-making devolution has potential to jeopardise the flood risk management role of spatial planning (Pottier et al. 2005). Nonetheless, this process allows individuals, businesses and other interested stakeholders to get involved through commenting on planning applications, or by lodging a planning application themselves. Government, both nationally and locally, is a significant financer of spatial planning and development, although the *Town and Country Planning Regulations 2012* set fees for those making planning applications, such that the general taxpayer does not bear all their cost (HM Government 2012).

In England, spatial planning as flood risk management can be used in support of structural options to reduce risk to households, but this is not always the case. Managed realignment, for example, requires reconsideration of the use of the land that may now be exposed to the sea, or may in turn be better protected than it was previously. However, to date, managed realignment has mainly been used for habitat creation, and not with regard to coastal town or residential property flood risk management (Esteves and Thomas 2014). Spatial planning and engineering share some similarities in flood risk management, then, but as is discussed below, they are also distinctly different in policy, scale, and application.

2.2 Engineering

Engineering is used for flood risk management in England by adapting the physical environment to reduce or alter flood risk. Twentieth and twenty-first century flood risk management in England involved, first, a movement toward national governance, policy and financing in the 1950s and 1960s, and, second, a movement toward devolved governance, increased local financing, and systems-scale engineering in the 1990s (Butler and Pidgeon 2011; Lumbroso and Vinet 2011). In the twenty-first century, there are increasingly projects that not only aim at flood hazard reduction, but also focus on flood impact reduction, or relocation of flood hazard through managed realignment of current defences. Nationally, the key players in engineering coastal flood risk management are Defra and the EA. Defra develop much of the flood risk management policy and provide significant funding, while the EA has a duty to develop and apply a strategy for coastal flood risk management in England (*Flood and Water Management Act 2010*, c. 29). Other risk management authorities listed in the *Flood and Water Management Act 2010* are the lead local flood authorities, district councils, internal drainage boards, water companies, and highway authorities.

Here we define structural adaptation as the collective decision-making and use of soft and hard physical interventions, to support, maintain or develop existing natural or human risk reducing features, applied to local to system scales (French 2001; Dunlap and Brulle 2015; Vanderlinden 2015). Structural hard defences are generally built to last decades, although their lifetime can be extended by maintenance and upgrades; when the Thames Barrier is 50 years old in 2030, it will require substantial maintenance and the replacement of electrical and hydraulic systems to continue to reliably operate (Lavery and Donovan 2005). Property-level engineering interventions such as pumps, elevated plug sockets or resilient rebuilding are defined as "property level protection", and are only discussed in this review under that title. "Structural" and "engineering" adaptation are henceforth used interchangeably, as they both suggest an assessment and management choice to physically intervene on the coastline.

The erosion and flooding future of the entire English coastline is assessed in Shoreline Management Plans (SMPs), each of which covers a significant length of coast and are underlayed by Strategy Studies of a smaller spatial extent. SMPs guide the level of engineering needed with one of four options. The first three may require some or significant engineering intervention – "hold the line", "advance the line", "managed realignment" – while "no active intervention" indicates the choice not to intervene with engineering (Defra 2006a). To date, managed realignment has mainly been used for habitat creation, and not with regard to residential property flood risk management (Esteves and Thomas 2014). Current rates of managed realignment are not, however, meeting those levels set out in SMPs; rates would need to increase five-fold should 550km be realigned by 2030 relative to a baseline of 2000 (Russell et al. 2018).

Between 2011 and 2016, £190 million was raised for flood risk management through the Flood and Coastal Resilience Partnership Funding Scheme (Partnership Funding), through Partnership Funding sources including public and private partner contributions, and the funding raised by other risk management authorities (EA 2016). Nonetheless, the national government continues to provide the majority of financing for public engineering works. In 2015-2016, the EA invested £741million in flood and coastal erosion risk management in England, to which an additional £31 million was raised in Partnership Funding (EA 2016), and of the £2.5 billion central government flood investment planned for 2015-2021, approximately 42 per cent will be dedicated to flood and coastal erosion risk management (Allison 2017).

2.3 Insurance

Despite the widened scope of engineering as coastal flood risk management in recent decades, there will always remain a residual risk of coastal flooding. Insurance can be used to prepare for the residual risk, such that should an event still occur, recovery may be more affordable, prompt and achievable. Insurance is used as flood risk management by redistributing the potential financial damages of flooding through the market. Insurance can also be used to enable or discourage development in hazard areas, increase property resilience, and encourage local and property-level protection actions. For example, using data-driven techniques to develop risk-reflective pricing insurance can discourage development in high-hazard areas through high premiums or enable development in high-hazard areas through insurance provision (Rumson and Hallett 2019).

The national government has a history of almost seven decades of agreements with the commercial insurance industry to attempt to provide widespread access to flood insurance, including coastal flood insurance. In theory, the Gentleman's Agreement made between the government and insurance industry in the 1960s "requested" that insurers provide coverage to all occupied dwelling; in practice, uptake on this offer by households was not universal (Penning-Rowsell, Priest and Johnson 2014). Following a series of serious river floods (1998, 2000, 2007) and the insurance industry's dissatisfaction with the Gentleman's Agreement, Flood Re emerged from the *Water Act 2014*. Flood Re is a reinsurance company mandated to "promote the availability and affordability of flood insurance" as well as "manage… the transition to risk-reflective pricing" for household premises (*Water Act 2014*, Section 64). The first of Flood Re's requirements suggests intervention in insurance and pricing to make it equitable: both available and affordable. However, the second part suggests leaving the insurance industry to determine pricing, as guided by flood risk. Funding for Flood Re comes from the government and a levy on insurers authorised to write home insurance in England

and Wales and party to Flood Re charge; further funding is raised through premiums and reinsurance. Insurance cover renewal mostly occurs on a yearly basis, however, with Flood Re legislated to last until 2039 (at which point premium pricing must be risk-reflective) insurance is also being applied at a decadal time scale. Similarly, although insurance policy is set nationally, its uptake and effects are felt much more locally, by households and businesses.

Flood insurance in the England today remains commercial and profit-driven and is predominantly the domain of government and national insurance industry (e.g. the Association of British Insurers, ABI). In the case of Flood Re, the government has entrusted the insurance industry to set the conditions for redistribution, guided by legislative requirements of affordability, accessibility and a transition to risk-reflective pricing. However, insurance as a flood risk management approach is also greatly affected by planning and engineering decisions. When planners now approve further development in the floodplain, their access to affordable insurance is not guaranteed by the *Water Act 2014*: Flood Re only applies to pre-2009 builds. This serves as a disincentive for future floodplain development, and along with the lack of guaranteed government-backed disaster relief funding, should discourage both developers and buyers from floodplain settlement. Yet when defences are built or enhanced, premium prices are rarely decreased, despite the implied risk reducing result of the new defence (Penning-Rowsell 2015). Despite insurance being increasingly recognised as part of coastal FRM, such as its more prevalent discussion in the most recent National Flood and Coastal Erosion Risk Management Strategy (EA 2020), its inclusion remains unusual and this work seeks to remedy that absence by its inclusion in this review.

3. Methods

This paper draws on a review of 124 papers and policies which focus on spatial planning, engineering and insurance as management approaches to coastal flooding. A broad literature and policy search was conducted across disciplines, including insurance law, spatial planning, engineering, and climate adaptation, and key terms: “coastal flooding”, “coastal flood risk”, “flood risk management”, “flood insurance”, and “flood planning. This extensive search on national and regional policy databases was supported by expert review from co-authors. Articles were selected on their focus on managing flood risk in England. Articles focusing solely on fluvial, ground and surface water were excluded, although articles with examples of successes internationally using planning, structural or insurance approaches were used to demonstrate opportunities for English flood risk management.

From these 124 papers and policies, the strengths, weaknesses, opportunities and threats (SWOT) of coastal flood risk management in England were identified. Strengths and weaknesses describe the positive and negative endogenous factors of the system that affect its ability to achieve its objectives (Comino and Ferretti 2016); how current funding models affect the effectiveness of insurance as coastal flood risk management, for example. Opportunities and threats capture the circumstances exogenous to the system that benefit or detriment the potential of the system to achieve its objectives (Comino and Ferretti 2016); how changing politics or climate might affect the effectiveness of engineered flood risk management. The opportunities and threats to these three approaches are used to consider in greater detail the resilience of coastal flood risk management in England; *resilience* describing a socio-ecological system's (e.g. England's coastlines) capacity to adapt to change, and assessing the magnitude of disturbance with which the system can cope before it changes to a radically different state (Adger 2006, p268-9). The complete SWOT analysis is provided in the supplementary materials, along with the accompanying reference list of the sources for these results.

To further guide the analysis, we posed questions around the same themes as those investigated by Tompkins, Few and Brown (2008), see Table 2. Integration is a process that combines or incorporates parts into a whole so that they can work together (Ran and Nedovic-Budic 2016). To explore the integration of coastal flood risk management, we compare and contrast the current roles of planning, engineering and insurance as coastal management for flood risk, by investigating aspects of responsibility, timing, cost, power, acceptability, equity, and effectiveness in the management process (Tompkins, Few and Brown 2008). We categorise these themes as per Alexander, Priest and Mees's (2016) three-part categorisation of flood risk governance evaluation foci: process, outcome and impact. *Process* describes the inputs, throughput and output of the decision-making process (e.g. nature of public participation in decision-making); *outcome* captures the implementation of outputs of the decision making (e.g. erecting a defence); and *impact* represents the resulting effect of the process and outcome (e.g. defence's impact on local flood risk). Here, the questions around responsibility, timing, cost and power are narrowed down to focus on process and outcome, whilst the questions of acceptability, equity and effectiveness focus on the impact of management decisions and actions.

Table 2 Questions to evaluate coastal flood risk management across planning, engineering and insurance approaches

	Issue, as per Tompkins, Few and Brown (2008)	**Loci of evaluation, as per Alexander, Priest and Mees (2016)**	**Question posed in this paper, regarding coastal flood risk management for residential properties**
1	*Responsibility*	Process & outcome	What responsibility exists around risk management: are regulations advisory or mandatory?
2	*Timing*	Process & outcome	Is management focused on existing and/or future residential properties?

3	*Cost*	Process & outcome	Who is financing the management?
4	*Power*	Process & outcome	Who is involved in the management and how?
5	*Acceptability*	Impact	Which aspects of risk are being managed for?
6	*Equity*	Impact	Who is bearing the risk of coastal flooding after management interventions?
7	*Effectiveness*	Impact	How are social and environmental changes accounted for in management?

The Source Pathway Receptor Consequence (SPRC) conceptual model is used to assess the acceptability of coastal flood risk management, by analysing which aspects of risk are being managed (Table 2, row 5). This model defines risk as the *consequences* – the experienced social, economic, health and other impacts of a flood event – of sources, pathways, and receptors interacting in a coastal flood risk system (see Figure 3) (Evans et al. 2006). The *source* is the flood event and its cause, while the *pathway* is the mechanisms by which the floodwater travels from the source to receptors. *Receptors* describe the environment, including society, affected by the flood. The model is frequently applied in engineering and management for system-scale risk assessment and management (Evans et al. 2006; HR Wallingford, Flood Hazards Research Centre, and Risk & Policy Analysts Ltd 2006; Sayers 2012; Narayan et al. 2014).

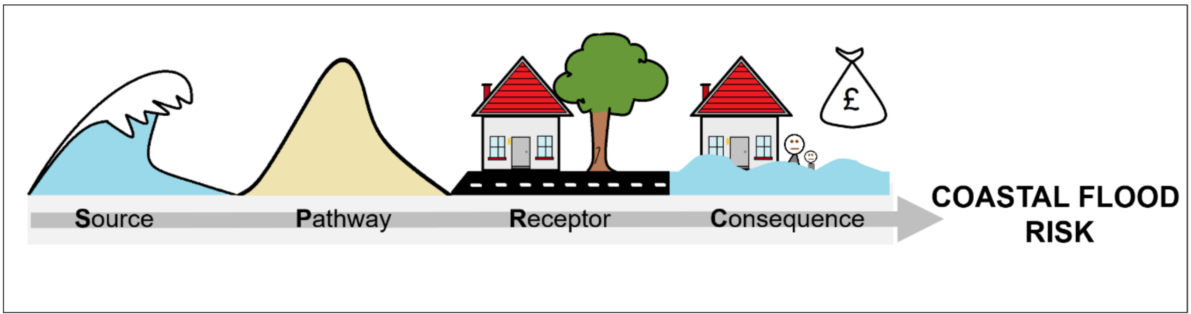

Fig. 3 The Source-Pathway-Receptor-Consequence (SPRC) model illustrating a coastal flood risk system (adapted from Department of the Environment, Transport and Regions, EA and Institute for Environment and Health 2000 p34, and Narayan et al. 2014, p17)

4. Results

Coastal flood risk management in England is multi-faceted and ambitious, seeking to reduce coastal flood risk to 100,000 homes between 2015/2016 and 2020/21 (Allison 2017), and ensure resilience of infrastructure and places in the face of climatic and coastal change (EA 2020). The section below provides further detail into the responsibility, timing, cost, power, and equity dynamics of the planning, structural and insurance adaptations being used to achieve this aim of coastal flood risk management in England.

4.1 Responsibilities

Different legislation and regulations guide spatial planning, engineering and insurance as flood risk management practices, and each of these regulatory frameworks and bodies designate distinct responsibilities. Here, we explore the mandatory and advisory responsibilities of coastal flood risk management approaches (see Table 2, row 1). Table 3 highlights how spatial planning and structural approaches are mainly guided by advisory regulations. This is contrast to the *Water Act 2014,* which specifically legislates the purpose of insurance in flood risk management.

Table 3. The use of regulations in coastal flood risk management approaches

	Advisory regulations[a]	*Mandatory regulations[b]*	*Explanation*
Spatial planning	+	+-	The EA must be consulted in planning application in flood risk areas (MHCLG 2006); although its recommendations are advisory only, they are generally followed (Pottier et al. 2005; Defra and Cabinet Office 2016; EA 2016).
Structural	+	+-	No nationally mandated defence standard: administering a SMP or EA recommendations is not compulsory (Defra 2006; *Flood and Water Management Act 201*0).
Insurance	+-	+-	Flood Re reinsurance of households is mandated by the *Water Act 2014*; for businesses and post-2009 builds structural insurance is often required by mortgage lenders (OECD 2016; Surminski 2018).

[a] Advisory regulations covers all other responsibilities, from departmental requirements to private regulation.
[b] In this analysis, mandatory regulations indicates there is a legal obligation to fulfill certain responsibilities.

+ This regulation type is used with regard to the specific flood risk management approach;
+- There is some use of this regulation type with regard to the specific flood risk management approach;
- There is limited or no use of this regulation type with regard to the specific flood risk management approach.

The use of spatial planning as flood risk management is a quasi-voluntary process. There are strict planning procedures outlined in the NPPF and mandated by the Town and Country Planning Acts which affirm the EA's consultee status on plans in the floodplain. Nonetheless, the direction and content of any advice the EA poses to Local Planning Authorities regarding flood risk remains advisory (Defra and Cabinet Office 2016). Despite this advisory status of the EA's response, in 2015-2016, 96.8 per cent out of 2,015 measured planning outcomes were defined to be "in-line" with EA flood risk advice (EA 2016). However, planning outcomes being "in-line" encompass the Local Planning Authority responding to a plan by refusing it, the applicant withdrawing it, accepting it after redesign, or accepting it under further investigation (EA 2016). This means that developments can be in-line with EA advice and still take place in Flood Zone 2 and Zone 3: areas of land where the probability of flooding is greater than 0.1 per cent in any year. This approach does not prevent all further development on floodplains; it does subject future development to assessment before it may proceed. It should therefore not surprising that development on floodplains continues to be observed (Porter and Demeritt 2012; Bell et al. 2015). In view of the continued development in the floodplains in England, it is possible that Parker's (1995) "levee effect" still holds true: development sparks the construction of engineered defences, sparks further development.

Similarly to spatial planning, there is no national legislation mandating government departments to build flood defences for risk reduction to established levels (Defra 2006a; *Flood and Water Management Act 2010*). The production of SMPs is encouraged but they are non-statutory documents: the first round of SMPs was published by 2000 (SMP1), and the first review was launched in 2006 with procedural advice from Defra (SMP2) (Defra 2006b). An exception is the Thames with regard to the *Thames Barrier and Flood Prevention Act 1972*, which includes paragraphs requiring a minimization of "any risk of danger to life or damage to property arising from floods or inundations caused by the overflow of the river downstream of the barrier" (p. 28), as well as outlining the requirement of the Council to compensate owners of occupiers of undefended land, injury be sustained because of the closing of the barrier gates (p. 37). However, even with this exception, there is no quantified risk levels to which coastal flood risk must be reduced by the barrier, and nor is compensation required for coastal flooding; it is required for injury sustained because of the closure of the Barrier. The other exception regards management realignment schemes, often undertaken to meet the UK's habitat compensation obligations to the Habitats Directive (Esteves and Thomas 2014; Brady and Boda 2016).

Regarding insurance as flood risk management, national legislation mandates the role the reinsurer Flood Re must play in making flood insurance both "affordable" and "risk-reflective" (*Water Act 2014*). Nevertheless, there is no obligation for insurers to participate in this reinsurance scheme, although the company Flood Re states 90 per cent of flood insurance writing insurers are now party to Flood Re (Flood Re 2017). Part 4 of the *Water Act 2014* describes a "Flood Reinsurance Scheme" (Flood Re) which must "promote the availability and affordability of flood insurance for household premises" and manage a "transition to risk-reflective pricing of flood insurance for household premises." However, the obligations of Flood Re, the company established to carry out the mandate of the Act, only apply to (a) household residences, and (b) post-2009 builds. Businesses and industry are not covered by the affordability aims of the *Water Act 2014*. Aside from the Act, most mortgage-lenders require buildings-insurance to acquire a mortgage – but this is not legally obligatory and does not apply for contents insurance (OECD 2016). Thus, while spatial planning and structural approaches are both guided by regulations for which compliance is urged but not mandatory, the *Water Act 2014* may have mandated the requirements of Flood Re as a flood risk management mechanism, but subscription to Flood Re remains voluntary.

4.2 Timing

Following on from examining mandatory and advisory responsibilities, there is the question as to the temporal focus of coastal flood risk management: are policies managing risk to existing residential properties, future residential properties, or both (see Table 2, row 2)? Both structural and insurance approaches to coastal flood risk management address, first and foremost, the risk posed to existing residential properties. As is evident in Table 4, spatial planning stands out as having the greatest impact on future developments.

Table 4 The management of coastal flood risk for existing and future residential properties

	Existing developments[a]	*Future developments*[b]	*Explanation*
Spatial planning	-	+	Provides control over future developments along the coast (Pottier et al. 2005; Carter and Sherriff 2011; Porter and Demeritt 2012; Bell et al. 2015; Ran and Nedovic-Budic 2016), but does not remove permissions for existing buildings (Kovats and Osborn 2016).
Structural	+	-	Existing developments are included in engineering proposals and funding assessments; recent and new developments are excluded (Defra and EA 2012).
Insurance	+	-	FloodRe applies to pre-2009 built private residential buildings (*Water Act 2014*), disincentivising further floodplain development (Flood Re 2016). Incentives could encourage resilient rebuilding (Dávila et al. 2014; Poussin, Botzen and Aerts 2014).

[a] Existing developments describes existing buildings, with a particular focus on residential properties.
[b] Future devlopments describes planned and non-existent residential property developments.

+ This flood risk management approach manages risk for existing/future developments;
+- There is some use of this flood risk management approach to manage risk for existing/future developments;
- There is limited or no use this flood risk management approach to manage risk for existing/future developments.

The focus of spatial planning as flood risk management is on future building developments. Planned developments that fall in flood zones are required to submit a risk assessment to the EA, with some exceptions (Defra and EA 2014). Planning is then used to determine whether proposed future changes to current land use situations are acceptable (Pottier et al. 2005; Green 2017). However, because of the advisory-only role that the EA plays regarding planning applications, developments do still occur in the floodplain. While nearly three quarters of floodplain development since 2001 has been in areas of low likelihood of flooding, an additional 23,000 homes have been built in areas with a 1-in-30 or greater chance of annual flooding from rivers or the sea (Bell et al. 2015).

By contrast, both structural and insurance approaches focus on pre-existing developments, often excluding new and future developments from consideration at all (see Table 4). Dwellings considered in applications for Flood Defence Grant-in-Aid (FDGiA) will only be considered if converted into housing or built before 1 January 2012 (Defra and EA 2012). Flood Re, the reinsurance scheme to provide affordable and accessible flood insurance, does not apply to post-2009 builds (*Water Act 2014*). Both approaches argue that this is to discourage further development in the high flood hazard zones. A post-2009 build may still be able to obtain flood insurance, but the government has not arranged with the insurance industry to require such flood insurance provision. It is thus possible for insurers to price premiums extremely high for post-2009 builds in areas of medium to high risk of flooding, or refuse to insure such households or businesses at all.

The application of engineering and insurance as flood risk management is therefore limited to pre-2011 and pre-2009 buildings respectively, but this limitation is a deliberate part of their role as flood risk management mechanisms. Conversely, the use of spatial planning as flood risk management depends upon its being applicable to future developments.

4.3 Cost

The third question posed in this review was *who* is financing coastal flood risk management (see Table 2, row 3)? Engineering and planning approaches share a dependency on public funds, whereas insurance draws primarily from households. As Table 5 highlights, the three different approaches to flood risk management in the England do not distribute the costs across funding sources – private individuals, businesses, government, and partnership combinations – in the same way.

Table 5 The distribution of coastal flood risk management financing across stakeholders

	Private (individuals)[a]	*Public (government)*[b]	*Business*[c]	*Partnership*[d]	*Explanation*
Spatial planning	+-	+	+-	+-	Regulation costs for government (DCLG 2017; Planning Inspectorate 2017; DCLG 2018). Planning applications can be private, business or partnership-led: private individuals and businesses may bear the cost of planning outcomes (Ennis 1996; Cheshire and Sheppard 2002).
Structural	-	+	+-	+-	Funded by government or partnership funding (EA and Maritime Local Authorities 2010; Defra 2011; Defra and EA 2012; EA 2013; Defra and Royal Daskoning 2014; Defra 2014; EA 2014). Businesses can invest in single-site defences (Defra 2011; Defra and EA 2012).
Insurance	+	-	+	+-	Purchased by individuals and businesses (Dávila et al. 2014; Flood Re 2016; Surminski 2018). Government provides minimal direct financing.

[a] Private finance provision describes individuals and households.
[b] Public describes government from national to local level.
[c] Business describes industry and companies.
[d] Partnership describes any combination of the preceding stakeholders.

++ This stakeholder provides significant funding for this flood risk management approach;
+- This stakeholder provides some funding for this flood risk management approach;
-- This stakeholder provides little or no funding for this flood risk management approach.

The direct financing of spatial planning is provided by the Planning Inspectorate, Local Authorities, and through planning application fees (DCLG 2017; Planning Inspectorate 2017; DCLG 2018). The direct costs include those of developing planning policy, of processing applications, and of developers adapting their plans to stay in line with planning regulations (Ennis 1996). Private, business and partnership involvement in both is possible. However, the most significant costs of spatial planning may be the cost of planning outcomes: decisions on how to utilise land changes land values, (financial) productivity and benefits derived from that land, supply and affordability of housing and office space, and access to land (Cheshire and Sheppard 2002; Cheshire et al. 2012). Cheshire and Sheppard (2002) argue that, overall, these outcome costs produce valuable benefits but also high costs – the latter of which favour those individuals with higher incomes, whilst the former increases inequality. The cost of spatial planning as flood risk management thus extends far beyond the Local Planning Authority.

While in planning, financing for changes are provided by applicants such as individuals or businesses, in structural management individuals rarely directly finance flood defences. Instead, management is financed by many sources, although central government funding continues to dominate. Private individuals seldom directly finance community flood defences, but they do pay through central taxation and, upon occasion, through local levies (EA and Maritime Local Authorities 2010; Defra and Cabinet Office 2016). Reasons for the lack of individual funding include the high costs of coastal flood defences, and the magnitude of coastal flooding as a threat (Committee on Climate Change 2016; Cabinet Office 2017). By contrast, HM Government has committed to spend £2.5 billion in capital funding for flood defences from 2015-2016 to 2020-21 (Defra and Cabinet Office 2016). This is to be composed of £600 million in partnership funding, whereby communities or business provide some of the funding for defences and of which £270 million was raised by September 2016 (Priestley and Rutherford 2016), including those schemes that may not meet the cost-benefit-ratios required for full Flood Defence Grant-in-Aid (FDGiA) funding from central government (Defra and EA 2012). FDGiA gives preferential weighting to schemes that reduce flood risk to deprived households, but the limited capacity of socially vulnerable households to contribute to flood risk management interventions continues to hamper their access to structural adaptation (England and Knox 2015). Despite a diversity of sources of funding for structural flood risk management, the dominant funding source remains the central government.

The reverse is true for insurance: government is the last direct funding source. Individuals and businesses foot the bill for their own insurance, and Flood Re has been set up so that even high-risk individuals “should” be able to afford it. This affordability has been achieved by linking maximum premium prices to the Council Tax band of the insured’s residential property, but Council Tax bands vary regionally and across the England and are not per se propertional to disposable income (Davey 2015). What may be an affordable price cap to insurance premiums in one region, may not be elsewhere. The role of government is in its policy partnership with the insurance industry. A combination of increased data and severe flooding in the late 1990s and early 2000s resulted in today's arrangement: the government provides flood defences and reduces future flood risk, and in return the insurance industry pledges to provide insurance for all levels of flood risk in the England (Penning-Rowsell, Priest and Johnson 2014; Penning-Rowsell and Priest 2015). Although government does not directly pay for insurance as flood risk management, an indirect partnership and financial obligation perseveres.

4.4 Power

In managing coastal flood risk, choices are being made as to who is involved in the decision-making and management process, and with that comes either a sharing of power or a withholding of it (see Table 2, row 4). Stakeholder involvement describes the breadth of stakeholder groups involved in the flood risk management process, and the depth of their involvement (Arnstein 1969). Begg (2018) suggests that in Europe there is trend to assign responsibility for flood risk management to local levels, but without a relinquishing of power. The legal responsibilities of stakeholders are explored in Section 4.1, but here the power and opportunity that stakeholders have to engage in coastal flood risk management is examined (see Table 6). In structural adaptation and spatial planning, there are established processes of stakeholder engagement in the planning and development stages. By contrast, insurance allows for little stakeholder involvement in the planning of its role as coastal flood risk management.

Table 6 The engagement of stakeholders in coastal flood risk management

	Private (individuals)	*Public (government)*	*Business*	*Explanation*
Spatial planning	+-	+	+-	Government, developers and the public can be involved in spatial planning processes (Pottier et al. 2005; Crichton 2008).
Structural	+-	+	+-	Inclusion of local scale and community (Thaler and Levin-Keitel 2016), but there are still limits to the engagement of the general public (Benson, Lorenzoni and Cook 2016).
Insurance	+-	+-	+-	The insurance systems and its funding mechanisms (private) are established by the ABI and national government (Green and Penning-Rowsell 2004); insurance gives individuals a change to be engaged in their own risk management (Crichton 2008; Filatova 2014).
+ This flood risk management approach significantly engages this stakeholder group; +- This flood risk management approach somewhat engages this stakeholder group; - This flood risk management approach does not engage this stakeholder group.				

Spatial planning for flood risk management involves multiple stakeholders, both for planning policy and in policy application. Planning applications in England have a strong element of stakeholder engagement: the public, developer and government are all involved to some extent in the process of applying, reviewing and approving a planning bid (Pottier et al. 2005; Crichton 2008). Pardoe, Penning-Rowsell, and Tunstall (2011) suggest that there is a stronger emphasis on negotiation regarding development on the floodplain in England, versus the USA, Austria, France and Spain. However, the contemporary planning approach comes both with high economic benefits and high economic costs, in which not all stakeholders have decision-making power (Cheshire and Sheppard 2002; Cheshire et al. 2012). Despite engaging a wide range of stakeholders, it is unclear whether their desires are reflected equally in planning outcomes.

Similarly to planning, carrying out structural projects generally includes stakeholder engagement measures. Increasingly, local and community stakeholders are involved in the process of allocating and funding structural flood defences (Thaler and Levin-Keitel 2016). There is a long history of stakeholder engagement in England, with regional committees established as early as the 1930s already localising some power and responsibility for flood risk management (Geaves and Penning-Rowsell 2016). Nevertheless, there is a struggle to engage the public in flood risk management because of, for example, dwindling numbers of the public involved and complex institutional arrangements complicating possible involvement (Geaves and Penning-Rowsell 2015). There is limited evidence of capacity-building for public involvement, such as through provision of resources, and while local stakeholders are actively sought to provide financing through Partnership Funding, they can do little to affect the process by which defence schemes are delivered and areas lacking financial capacity or assets to attract state funding may struggle to participate (Begg, Walker and Kuhlicke 2015; Begg 2018). Although locally stakeholders are generally involved, much decision-making power remains vested in established hands.

Compared to other nations, the insurance system in the England is inclusive and requires stakeholder agreement (Penning-Rowsell 2015). Since the 1960s, the government and insurance industry cooperated on flood insurance through the Gentleman’s Agreement, and following a subsequent series of agreements in the early 2000s, agreed on Flood Re as a balancing of responsibilities. Nonetheless, in this process of insurance as flood risk management, only *those* stakeholders have generally been present: insurers not part of the ABI, local stakeholders and individual households have largely been excluded – insurance as flood risk management is decided at a national level (Dávila et al. 2014). While individuals are very much at the heart of insurance as flood risk management in terms of it incentivising household property-level protection (Crichton 2008; Filatova 2014; Oakley 2018), individuals appear to have minimal influence on longer-term insurance policy and terms.

4.5 Summary of coastal flood risk management processes and outcomes

This review highlights the similarities in coastal flood risk management across planning, structural and insurance approaches, such as the underlying role for legislation assisted by non-statutory documents, and the focus of both engineering and insurance on protecting existing residential properties. The results also identify differences both in the process and the outcome of these management approaches, where planning generally redistributes risk locally and is a heavily government-driven process, while insurance is largely coordinated by the insurance industry and redistributes risk at a national scale. In terms of temporal scale, where planning focuses on future dwellings, the role of structural adaptation is on managing flood risk for existing residential properties; post-2011 residential builds and conversions are not even considered by FDGiA proposals (Defra and EA 2012). These three approaches to managing coastal flood risk in England are driven by different legislation and policies, funding sources, and models of stakeholder engagement, creating both a strong and diverse model of risk management, as well as potential for tensions when their goals and methods are not aligned.

5. Discussion

Having reviewed the processes and outcomes of spatial planning, engineering and insurance coastal flood risk management approaches for households through questions around responsibility, timing, cost and power, this section discusses the impacts of flood risk management approaches on residential properties through questions around their acceptability, equity and effectiveness.

5.1 Acceptability

This section explores the acceptability of risk by asking which parts of the SPRC conceptualisation of coastal flood risk are being managed by each approach, and which elements receive less focus (Table 2, row 5).

The main demonstrated use of spatial planning as flood risk management in England is in managing receptors such as residential properties. Its application to manage the hazard, pathway and consequence has been less extensive. Planning is used to make (explicit or implicit) cost-benefit analyses of future development on floodplains, including that of residential properties, versus development elsewhere (Parker 1995; Green 2017). There is an attempt to direct new development away from low-lying areas along the coast, reducing loss susceptibility and vulnerability (Pottier et al. 2005). However, there is further potential for spatial planning to be used in responding to sources and pathways. Managed realignment of flood defences and accompanying land-use change exemplifies management of *where* extreme water levels occur, and *how* that water might reach receptors, through a combination of engineering and spatial planning (McBain 2012). To date, the primary goal of management realignment has been habitat creation, despite it being suggested within the SMPs nationally that another almost 500km of the coastline should be realigned by 2030, for multiple coastal flood risk management purposes (Committee on Climate Change 2013; Scott and Armstrong 2015). Coastal Change Management Areas, introduced in the NPPF 2018, provide an additional planning tool to support possible relocation of vulnerable residential properties on the coastline with significant rates of future shoreline change. Consequences could be further managed through the inclusion of damage-reducing strategies – residential property and development scale structural adaptation – in development applications, and this is increasingly encouraged in floodplain development (Defra 2016), but it is not mandatory. As is highlighted in Figure 4, spatial planning mostly manages flood risk to receptors – i.e. households – and there is increasing discourse on its potential to manage risk pathways.

Structural adaptation can have widespread application across the SPRC framework but is traditionally focused on the source and pathway (see Figure 4). Engineering can address the source to reduce impact on pathways and receptors, such as defences and houses, as well as alter pathways themselves by shifting from hard to soft defences, for example. Soft defences and maintenance of natural defences including marshes and wetlands to affect the hazard event (source) itself are increasingly carried out (Sayers 2012; Allsop and Burgess 2014; Narayan et al. 2016). In general, engineering projects measure their effect on reducing the consequences to receptors, and residential properties are often prioritised in such assessments. Nevertheless, these assessments are usually narrowly focused on Expected Annual Damages (EAD) or economic cost-benefit analyses, and rarely encompass vulnerability, social or environmental accounts of who is experiencing the loss (Brown and Damery 2002; Kind, Botzen and Aerts 2017). Nonetheless, the explicit application of the SPRC framework in engineering literature and assessments suggests that there may be an increasing attention for receptors and consequences, with a potentially wider consideration of the characteristics of receptors and consequences (Zanuttigh 2011; Narayan et al. 2014).

In contrast to engineering and spatial planning, insurance has dominantly been used in England to manage the consequences of coastal flooding to residential properties and other assets (see Figure 4). Insurance provides compensation for the consequences of flooding and aids in the recovery from an event . Insurance has no direct effect on the source or pathway element of a flood hazard. Studies on insurance from the Netherlands, France, and the USA demonstrate that insurance can be used to encourage household behaviour to adapt potential residential properties (receptors) to be better able to cope with flood hazards (Botzen, Aerts and van den Bergh 2009; Poussin, Botzen and Aerts 2014; Kunreuther and Pauly 2015; Abraham and Chiappori 2015), but there has been little similar research in England. This adaptive use of insurance is rarely applied in England and it has as yet been little incorporated in insurance premium prices or deductibles (Harries 2009; Dávila et al. 2014). Nevertheless, there is increasing attention to the potential use of insurance to incentivise household resilience and resistance measures, expressed both by Flood Re and the EA (Flood Re 2016; EA 2020)

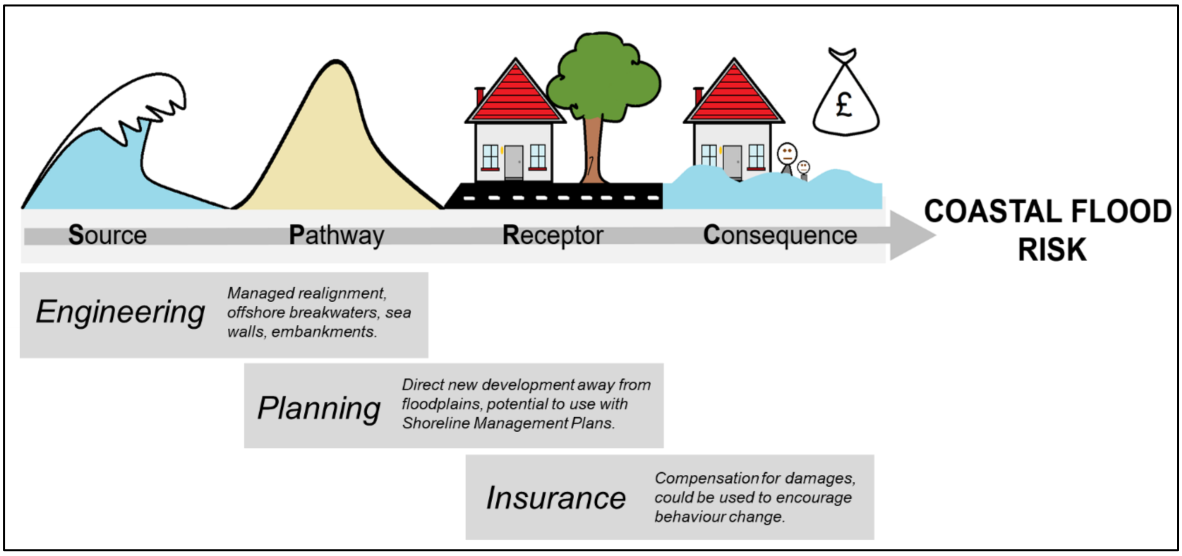

Fig. 4 The elements of planning, engineering and insurance coastal flood risk management that address parts of the Source-Pathway-Receptor-Consequence (SPRC) conceptualisation of flood risk. (Adapted from Department of the Environment, Transport and Regions, EA and Institute for Environment and Health 2000, p34, and Narayan et al. 2014, p17)

5.2 Equity

The equity of risk in coastal flood risk management is another form of impact evaluation: how do coastal flood risk management approaches redistribute the costs and risks of flooding and adaptation (see Table 2, row 6)? With no redistribution, high-risk households would be expected to manage and bear the costs of coastal flooding by themselves. However, planning, engineering and insurance all play a role in redistributing risk from exposed residential properties.

Unsurprisingly, a key role for planning is the *spatial* redistribution of coastal flood risk. By directing development away from flood-prone areas, planning can redistribute who is and who is not occupying these spaces. In practice, the risk redistribution role of planning is less clear. If effective, one would expect flood risk to be socio-economically dispersed as a result of spatial planning. However, in 2016, low-income households were eight times more likely to be located in coastal floodplains than more affluent household (Quids in Reader Survey, October 2016, in Hurman and Wells 2017). High levels of deprivation persist at the coastline (assessed by multiple indices of deprivation, low levels of average pay and economic output), as is being experienced in towns including Jaywick, Blackpool and Skegness – to name a few (Select Committee on Regenerating Seaside Towns and Communities 2019). This does little to suggest that past spatial planning has equally distributed coastal floodplain occupancy. Sayers, Penning-Rowsell and Horritt (2017) similarly find that geographic flood disadvantage is highly concentrated: "over 50% of the population exposed to flooding in the most vulnerable neighbourhoods located in just ten local authorities" (p. 347). Thus, while planning could be used to encourage sensible economic development and reduce vulnerability through coastal flood risk management, it appears to be concentrating risk on particular population groups rather than redistributing it. Society is faced with more risks compared with half a century ago, due to an increase in the hazard (e.g. sea-level rise), increasing exposure (e.g. more population on the coast) and changing vulnerability (e.g. loss of or change in industry), leading to a changing exposure with time. Regeneration (e.g. new sectors of industry, investment in tourism) has the potential the change this, which may mean policies are applied differently in the future.

Engineering is dominantly funded by central government in England, thereby redistributing the financial burden of coastal flood risk across taxpayers nationally. However, Partnership Funding shifts some of that financial burden back to the local scale by expecting local stakeholders to financially support flood defence schemes. Partnership Funding projects are designed to allow more structural projects to proceed, but rural areas with small populations struggle to meet the necessary requirements and Partnership Funding accounts neither for the reduced spending capacity of economically struggling towns and households, nor for the reduced networks and social adaptation capacities of coastal communities (Lindley et al. 2011; Begg, Walker and Kuhlicke 2015). The Committee of Public Accounts (2012) expressed concern that Partnership Funding would leave the public uncertain as to who is responsible for flood defences. Nationally there appears to a specific preference for defence of densely populated areas: the National Flood Resilience Review included a specific focus on raising the defence standards of "core cities" to the level of protection London enjoys with no comparable or proportionate specific focus on rural, vulnerable or deprived areas (Defra and Cabinet Office 2016). While national funding support for engineered coastal flood risk management thereby redistributes the costs from exposed residential properties, which are often vulnerable in more than ways than solely the flood exposure (e.g. deprivation), Partnership Funding returns some of those costs back to the local scale.

The traditional role of insurance is to redistribute some of the financial risk of flooding beyond being endured solely by those affected by a flood event. In England, insurance plays a significant role in risk redistribution, moving the costs of being flooded out of the local level and onto the national scale – even international, through reinsurance (Dávila et al. 2014; Filatova 2014). However, that redistribution is only effective for those households that are insured, and the number of insureds may be in decline: from 2008-2009 to 2015-2016 the proportion of working adults with contents insurance had declined from 65 per cent to 59 per cent (Rowlingson and McKay 2017). Similarly, funding mechanisms are decided nationally and the government provides no direct funding for insurance for households: households pay the price of insurance themselves. Although the purpose of insurance is to redistribute financial risk more widely, there are threats to its effectiveness in achieving that purpose, not the least because the current lack of incentive for households to manage their own flood risk and therefore insurance prices, and continued challenges in insuring those who are most vulnerable: such as those vulnerable populations living in exposed locations (England and Knox 2015)**.**

5.3 Effectiveness

Many of the results and the preceding discussion have focused on the state of coastal flood risk management today, but neither the environment nor society are static. A measure of the enduring effectiveness of this management is the extent to which it is resilient to uncertain future social and environmental changes on the English coastline (see Table 2, row 7). This section thus interrogates the scope of existing management policies to be resilient to the uncertainties of future governance, financing and climate change (Defra and Cabinet Office 2016; OECD 2016.)

Examining governance first, spatial planning has had its share of policy change at the national scale. Since 1992 there have been no less than four national guidance documents on planning for flood risk management (Department of Environment, MAFF and Welsh Office 1992; DETR 2001; DCLG 2006; DCLG 2010; DCLG 2012b), but throughout these planning changes the persevering trend has been minimal mandatory prohibition of development of the flood plain (Pottier et al. 2005; Richards, White and Carter 2008; Krieger 2013). Based on the relative stability of planning regulations regarding flooding, despite frequent changes in policy, one might assume policy will remain stable in the face of future governance evolution also. By contrast, structural adaptation has changed from a dominantly single-asset focus to systems-scale in the past few decades, there has been the development and renewal of SMPs, and changed funding mechanisms (Defra 2006a; Defra 2006b; Defra 2011). The focus on household resilience and resistance to flood risk has increased in recent policies also (Defra and EA 2011; EA 2020). Governance of coastal flood risk from an engineering perspective thus appears to shifting, but with little data on household awareness of flood risk let alone preparedness for it and financial shortfalls regardless of defence or non-defence SMP aspirations (Russell et al. 2018), it is unclear how future governance changes will evolve and change management for this approach. Flood insurance policy has enjoyed relative stability since the 1960s, excepting a tumultuous period in the 2000s out of which Flood Re was eventually produced. The medium-term future for the English flood insurance model is spelled out in the *Water Act 2014*. However in the longer term, with Flood Re expiring in 2039, unless flood risk decreases for high-risk groups, flood insurance may no longer be affordable to the same range of population (and risks), and its risk-redistribution role reduced (Penning-Rowsell 2015). Data on insurance penetration in England remains scarce, but Rowlingson and McKay (2017) indicate a decline in the proportion of working adults with contents insurance from 2008-2009 to 2015-2016, mainly due to the inability to afford it. Flood Re also has few mechanisms to incentivise risk reduction at the household level, despite household resilience through resistance or resilience property level measures being one way to reduce the costs of post-flood reinstatement for insurers (Oakley 2018). Today's insurance policy offers stability and resilience in terms of its multi-decadal lifetime and goals, but its effectiveness is uncertain.

Financial change affects current and future demand for development along the England's coasts, changing planning priorities. A booming property market may encourage further incursion on the flood plain, but a struggling economic period may lead to a decline in government financing for long-term planning and other management options. Some coastal cities experience great development pressures today; others are in decline (Select Committee on Regenerating Seaside Towns and Communities 2019). Conversely, spatial planning affects the economic situation of areas. A change in local planning can encourage financially logical incursion onto the floodplain where previously it was prevented (Pike et al. 2016). Engineering, in turn, is a centuries-old part of flood risk management in England: the dependency on engineering is too great for it to lose all support (Butler and Pidgeon 2011). However, the means by which engineering projects are funded affects which places get the investment, and where gets overlooked (Defra and EA 2012; England and Knox 2015). Funding beyond the incumbent government's funding programme and parliamentary dissolution is not certain, but investment today is investment for tomorrow, and thus there is some ability for contemporary engineering to deal with future uncertainties in financing. Insurance too, should offer resilience to financial uncertainty. Flood Re was, after all, developed as to provide longer-term assurances of accessible and affordable flood insurance for households. Nonetheless, it is not certain that flood insurance will be universally affordable before 2039, let alone after (Davey 2015). Furthermore, there persists the risk of insurance company insolvency from significant hazard events (Green and Penning-Rowsell 2004; Penning-Rowsell and Priest 2015). Planning, engineering and insurance approaches to managing coastal flood risk for households all share some financial certainty by virtue of their current prevalence and necessity, but equally each is threatened by changing funding models and the uncertainties of flood risk.

Assessments of the effects of a changing climate on coastal flood risk suggest increases in coastal flood risk to households in England – not solely because of the changed climate but also because of a continued increasing coastal population (Hall et al. 2003a; Wadey, Roberts and Harris 2013; Committee on Climate Change 2016). Projections on the expected levels of sea level rise vary widely, however, and there is further uncertainty around the relationship between sea level rise and changed coastal flood risk (Lewis et al. 2011; Edwards 2017). Under the NPPF, the EA provides climate change allowances for incorporating future flood risk into current planning applications (DCLG 2012a; MHCLG 2014), and the "Future Projections of UK Flood Risk" report provides estimations of extreme water levels, which can also be used in planning for future change (Sayers, Horritt and Penning-Rowsell 2015). Planning can be used for pre-emptive climate change adaptation, but because of other development pressures and uncertainties of change, the incentives to do so are sparse. By contrast, climate change must be considered in assessment and applications for EA funding for engineered flood risk management (EA 2010). The new UK Climate Projections will help to make more informed decisions in managing flood risk with climate change. For instance, this is particularly advantageous compared with UKCP09 due to probabilistic projections for new families of scenarios and high resolution outputs (Met Office 2018). Nonetheless, despite increasing attention and knowledge on coastal community adaptation, there have been no national proposals for long-term, sustainable adaptation strategies (Kovats and Osborn 2016). Climate change also endangers the risk-reducing ambitions of Flood Re for 2039 as households may face greater rather than reduced exposure to coastal flooding, and increases the uncertainty of the role and effectiveness of insurance as flood risk management. The uncertain effects of predicted climate change affect the ability of the insurance and reinsurance market to provide affordable premiums and pay out claims post-event (Crichton 2008; Penning-Rowsell and Priest 2015). Despite an awareness of the increasing risks posed by climate change, the current models of planning, engineering and insurance in England may therefore not be well-constructed for resilient adaptation.

5.4 Relevance of coastal flood risk management impacts to an international audience

Sections 4 and 5 outlined the results and further discussion of a SWOT analysis of coastal flood risk management in England across planning, engineering and insurance approaches, the results of which are summarised in Table 7.

England has a long history of using planning, engineering and insurance to reduce and manage coastal flood risk, but the flexibility within policies does not always benefit risk management aspirations. The general combination of legislated and advisory regulations allows for flexibility and localisation of flood risk management, but that flexibility also allows for continued development of the floodplain and leaves up to 41% of working adults with no contents insurance. There is no legislation mandating to what standards flood defences in England need to be built, unlike in other European countries such as the Netherlands (Defra and Cabinet Office 2016; Roos et al. 2017), but there are policy documents such as SMPs outlining the planned structural interventions around the coast nationally. In the Netherlands, flood risk is addressed through a “safety chain” addressing the entire flood risk management cycle, and of the three layers of safety measures the first includes *legal safety standards* for reduction of flood probability, while the remaining two layers encompass land use land use planning and preparedness (Jong and van den Brink 2017).

Despite changing policies, the intent of planning and insurance have remained relatively stable in the recent past, discouraging floodplain development and seeking to provide affordable insurance through private markets. Flood insurance industries have markedly varied arrangement by country, and while the United States National Flood Insurance Program has been found to decline housing development in coastal zones (Browne et al. 2019), it is beset by financial challenges (Silvis 2018). By contrast, the continued private market insurance for flood damages offered in England, although requiring government commitments of flood protection and a legislated reinsurer Flood Re, has not yet faced the same financial crisis. Although the evolution of the Gentleman’s Agreement to Flood Re took years of dialogue and the pressure of multiple severe floods, the English flood risk management system shows both constancy and an ability to adapt to changing drivers and exposure to coastal flooding.

Similarly, management frameworks for engineering have shifted from a scheme-by-scheme focus to systems-based management, and more recently households themselves are now being expected to take resilience and resistance measures also. Nevertheless, the shift to household resilience is accompanied by a repeated long-term commitment made in 2020 to invest in coastal (and other) flood defences by national government (HM Government 2020). While current household capacity to be an actor in coastal flood risk management is unclear, the continued policy review at both national (e.g. national flood and coastal erosion risk management strategies) and regional (e.g. SMPs) scales ensures issues are flagged early, researched, and improved. An integrated coastal flood risk management system for England may still be challenged by different time scales and could do more to achieve effective and equitable redistribution of risk. However, it demonstrates how, at a national scale, dialogue and policy alignment between different sectors such as land use planning, engineering and insurance supports adaptable and long-term management.

Table 7 An evaluation of coastal flood risk management across planning, engineering and insurance approaches

	Question posed in this paper, regarding coastal flood risk management for residential properties	Results from this paper
1	Responsibility: what responsibility exists around risk management: are regulations advisory or mandatory?	Spatial planning and engineering approaches are largely guided by regulations for which compliance is urged but not mandatory. Flood Re is a mandated reinsurance company, but subscription to it is voluntary.
2	Timing: is management focused on existing and/or future residential properties?	Engineering and insurance focus on pre-2011 and pre-2009 residential properties respectively. The main spatial planning focus is on future developments.
3	Costs: who is financing the management?	Engineering and planning approaches depend on public funding. Insurance is financed primarily from householders themselves.
4	Power: who is involved in the management and how?	Engineering and planning have established stakeholder engagement processes; insurance allows for little stakeholder involvement. The power of involved stakeholders is limited in all approaches.
5	Acceptability: which aspects of risk are being managed for?	The three approaches focus on different aspects of SPRC, which engineering managing the source and pathway, planning the pathway and receptor, and insurance the receptor and consequences.
6	Equity: who is bearing the risk of coastal flooding after management interventions?	All three approaches have the capacity to redistribute risk, i.e. insurance shares costs between lower and higher risk groups. The extent to which risk is being redistributed and addressing vulnerability is limited.
7	Effectiveness: how are social and environmental changes accounted for in management?	Uncertain finances and climate change endanger the long-term sustainability of current coastal flood risk management practices for households.

6. Conclusion

Coastal flooding poses a major risk to England, which has been recognised and managed for centuries. In recent decades, the focus of managing coastal flooding has shifted from flood prevention to risk management, with a recognition that with any engineered defence there will always be a residual risk in need of management. This paper explores areas of tension in the existing spectrum of management approaches through spatial planning, engineering and insurance. Through the SPRC model of risk and a series of questions posed by Tompkins, Few and Brown (2008) regarding coastal management, we used the results of a SWOT analysis to examine the similarities and divergences between the management approaches.

Local stakeholders and households are increasingly expected to be involved in flood risk management; through providing financial resources for Partnership Funding, or taking resilience and resistance actions for residential properties. However, with rising sea levels and accompanying probabilities of extreme high tides and storm surge of more severe coastal flooding, the ability of households and local stakeholders to manage *coastal* flood risk – an high impact, low frequency event – is risky in and of itself. The effectiveness of property level protection against coastal flooding may be limited, and the costs of coastal defences can be staggering even for short sections of coastline. This paper indicates a lack of clarity of the distinction between stakeholder engagement and their empowerment in decision-making, as well as their expected responsibilities. Future decision-making needs to be clear on what responsibilities are expected of households specifically for coastal flood risk (separate from other types of flooding) and if it wants to raise more funding may need to be more open to being a *partner* in partnership funding, not the leader of the process. A similar system in England to that in the Netherlands, where there is clarity as to the legislated standards and central government dictated decision-making, in contrast to local flexibility and responsibilities, may help clarify the expectations of households and other local stakeholders in managing coastal flood risk.

The way forward may be increased attention, in both research and policy, to the coastal flood risk management *system* of England, continuing trends apparent since the Foresight Future Flooding report (Evans et al. 2004). While planning, engineering and insurance approaches all redistribute the costs of management and flood events from the most exposed households, this review highlighted that each also suffers from limitations to its equitable application: Partnership Funding may be more readily accessed in less deprived areas where there is significant wealth or enterprise activity, planning has not prevented continued disparity in coastal and floodplain areas, and insurance remains inaccessible to a significant proportion of the population. Despite evolving policy, central government continues to bear most costs of coastal flood risk management as well as hold most decision-making power. SMPs have highlighted areas around England where the long-term preferred management action is not to defend; it is especially in these locations at Coastal Change Management Areas could be key in empowering local stakeholders in planning for long-term change, but also where there is the greatest need for policy and practical interaction between engineering, planning and insurance to ensure the long-term financial and social acceptability of the decisions being made.

If long-term management plans such as SMPs and Coastal Change Management Areas can be moved from paper into practice, they may provide aspirational examples of long-term coastal adaptation for other countries facing significant current and future coastal flood risk. Managing the coast in the face of increasing risk with continued limited resources requires a systems approach to coastal flood risk management where the net effect of spatial planning, structural adaptation and insurance approaches, together with other elements such as flood warnings, are considered as a whole. Progress has been significant over recent decades, but what this paper shows is there is much further to go. Further integration is challenging, but worth the effort to explore.

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