UK Parliament POST

POSTNOTE

Number 647 July 2021

Coastal Management

The UK coastline is shaped by interactions between complex social, ecological, and physical processes. Increasing coastal flood and erosion risk is a major climate adaptation challenge. This POSTnote examines coastal management in England, associated issues and how an adaptive approach can better prepare the country for uncertain future sea level rise under climate change.

Overview

- Sea level rise will continue over the coming centuries, increasing the frequency and magnitude of coastal hazards.
- Growing coastal populations and the value of assets on the coast are increasing exposure to coastal flood and erosion risk, with a third of people exposed to frequent coastal flooding in the top 20% most vulnerable neighbourhoods.
- Coastal management in England is guided by the new Flooding and Coastal Erosion Risk Management strategy, but it is not clear if the strategy can address the potential scale of future risks.
- Challenges remain around the planning, funding, and delivery of coastal management. Some options may also be challenging to deliver without gaining the acceptance of local communities.

Background

Coastal management seeks to reduce risk of flooding and erosion to communities, infrastructure, and assets on the coast. Cultural heritage sites and important ecosystems located in the coastal zone are vulnerable to coastal change (flooding and erosion).[1–3] Coastal flood risk is second in the national risk register.[4] Low lying coastal regions are susceptible to flooding, with 520,000 properties in England having >0.5% annual coastal flooding risk.[1] Currently, around 8,900 properties are in areas at risk from coastal erosion.[1] Infrastructure along the coast includes 7,500km of road and 520km of rail as well as power stations,[5] ports and industrial facilities such as oil refineries,[6] gas terminals and chemical plants.[1,5,7]

Coastal management is devolved. In England, it is undertaken in line with the national Flood and Coastal Erosion Risk Management (FCERM) strategy published in 2020,[8] through an annual action plan set out by the Environment Agency (EA). While improved management and forecasting have reduced damages from coastal hazards of comparable magnitude since the previous century,[9–12] coastal development is increasing exposure of populations and assets at the coast.[13] Temperature rise in the 20th and 21st Century has also committed the Earth to centuries of sea level rise (SLR) (Box 1),[14,15] increasing coastal hazards. This includes greater risk from storms contributing to increased flood and erosion risk.[16] Following major coastal flooding in 1953,[17] the dominant approach to risk mitigation has been engineered ('hard') defences, such as sea walls and storm surge barriers. However, the use of natural habitats, such as salt marsh, to manage coastal risk may be more economically sustainable with under 0.5m SLR [18,19] as reflected in the EA's FCERM strategy.[8]

The changing coast

There are considerable challenges in projecting how coastal flood risk will evolve as climate changes. As elsewhere,[20] increased UK flood risk has mainly been due to increasing asset exposure at the coast.[2,21] Predicting changes in social and economic conditions, including future adaptation, and their influence on future flood risk is challenging.[22,23] Beyond 2050, increasing rates of SLR are likely to become the main driver of UK coastal flood losses.[23] Coastal flood risk increases disproportionately for an equivalent global warming level compared to flood risk from other sources (such as river and surface water flooding).[24] Softer or unconsolidated coastal rock types are more susceptible to erosion.[25]

Compound flooding occurs when sea, river and/or surface run-

Box 1: Uncertain Future sea level
Future coastal flood risk assessments rely on projections of future sea level (POSTnote 555). Despite advances in modelling the land ice contribution,[26,27]policy responses will have to account for persistent uncertainty in future SLR. For the UK, high resolution regional projections of future sea level to 2300 are available through the UK Climate Projections 2018 (UCKP18).[28] These provide future sea level projections under a set of low, medium and high greenhouse gas concentration emissions scenarios. SLR will be greater further south in the UK, with UKCP18 marine projections ranging from of 0.29-1.15m by 2100 for London compared to 0.08-0.9m for Edinburgh.[29] Projections range from 0.6-4.5m by 2300 around the UK and across emissions scenarios.[28,29]In addition to these, a high end climate scenario (H++) projects SLR of 1.9m by 2100 and guides projects requiring a high standard of protection.[29] The third climate change risk assessment similarly suggests the UK should prepare for up to 2m SLR by 2100 in the event of extreme Antarctic melting.[30]

off happen concurrently or in close succession causing high water levels, with particularly adverse consequences for coastal communities.[31–36] Compound hazards are a relatively under explored aspect of coastal flood risk, especially when they occur with an extreme high tide superimposed on SLR.[37,38] Land elevation and prevailing storm tracks lead to increased frequency of compound flood hazard in the west and south west of England.[31] Compound flood risk in Northern Europe is likely to increase under climate change,[39] but localised projections are challenging to generate[40–42] and uncertain.[39]

Various modelling approaches are used to project coastal risk under climate change, but there are modelling challenges:

- **Scale.** Simulating large regions of coast at high resolution (100's of km) is computationally expensive,[43–45] so fixed, rather than evolving shapes of the coast are often used in flood models.[44] Coastal change processes, such as sediment transport, also occur over large scales that are challenging to simulate.[22,46] There are also issues around downscaling climate variables from global to local scales.[46]
- **Validation.** While the representation of climate, morphological and wave processes has improved in flood models,[22,44,47–51] more observational data over time and across locations can improve hazard model validation.[52]
- **Complexity**. Coastal erosion is highly localised and is dependent on coastal geology and geometry such as unstable complex cliffs,[53,54] ecology and wave direction,[55] and timing of storm events in relation to tides[51,56,57] (impacts are greater at high tide). Coastal erosion can be highly episodic.[58] Extreme sea levels and erosion interact;[59,60] for instance, beach profiles can change in response to storm events.[61] Airborne spray, an important flood source, is rarely included in flood hazard models.[44] Some physical and biological processes are poorly understood and may not be represented in models, driving uncertainty over longer timescales.[62] Process interactions are computationally expensive to capture but not doing so can underestimate the hazard.[37,63] Modelling natural replenishment of sediment to beaches after storms remains a challenge[58].
- **Social and economic change**. How human systems will respond to climate change and SLR, and whether policy will be adequately formulated and funded to address challenges around social acceptance is a major source of uncertainty.[23] To address this, scenarios have been developed to represent different development pathways ranging from high levels of mitigation to continued emissions growth. Projections of future coastal change are made for each scenario, or under an average emissions scenario, but their likelihood cannot be quantified. Questions around ethical and equity implications of policy are beyond the scope of standard modelling approaches, and as with other aspects of climate policy require complimentary qualitative approaches to address.[64]

Monitoring erosion and flood sources
The National Network of Coastal Monitoring Programmes of England collates monitoring data for the English coast by region.[65] Monitoring of interlinked processes such as SLR, storm activity, erosion and sedimentary processes[66] and social and economic change is needed for effective coastal management.[67] Monitoring of erosion is largely based on ground and air based surveys.[68] Advances in satellite remote sensing will increasingly improve understanding of coastal change.[69] New approaches to automated monitoring may provide real time information for emergency management and improve flood forecasting.[70]

Coastal management policy
Defra is the Government department responsible for policy on FCERM in England. Risk Management Authorities (RMAs) made up of the EA, Lead Local Flood Authorities, District and Borough Councils, Coast protection authorities, water and sewerage companies, internal drainage boards and Highways authorities work in partnership to deliver FCERM.[71] RMAs with oversight of erosion risk management are Coast Protection Authorities – local authorities within a maritime district as defined by the Coast Protection Act 1949.[72] Regional Flood and Coastal Committees set levies to fund priority regional FCERM works carried out by the EA.[73] RMAs can apply for Flood Defence Grant in Aid and Local Levy funding for FCERM work.

Flooding and Coastal Erosion Risk Management
Under the Flood and Water Management Act 2010,[71] RMAs are required to cooperate to deliver coastal management in line with the FCERM strategy. [8] The strategy's primary goal is to 'create a nation more resilient (Box 2) to future flood and coastal erosion risk',[8] with £5.2 bn pledged over 6 years from 2021.[8] The National Infrastructure Commission (NIC) recommended FCERM funding be based on delivering standards of resilience to flood magnitudes above an annual probability threshold.[73] Despite public support for this,[74,75] resilience standards were not adopted in the Government's FCERM Strategy, due to a lack of agreed methods and definitions for assessing and quantifying coastal resilience. Instead, the level of central government funding for FCERM projects is determined through variants of benefit-cost analysis (BCA),[8] in line with previous approaches.[76] BCA compares lifetime financial costs of defence projects to potential economic damages avoided (benefits),[77] following set appraisal methods.[77,78]

Shoreline Management Plans
FCERM is implemented through Shoreline Management Plans (SMPs) each covering one of 22 primary areas dividing the coast of England and Wales.[79] The plans are undergoing a

Box 2: Coastal Resilience
Policies increasingly promote resilience in coastal management. However, challenges remain around defining and measuring resilience in practice, and applying it to coastal management.[80,81] Resilience is commonly defined around the ability of a system to withstand, recover from and adapt to disturbance.[81] [82–84] In the context of infrastructure systems (POSTnote 621), the NIC adds the ability of a system to anticipate disturbance to its definition and advocates resilience stress testing.[85] Although frameworks have been proposed,[80] formalising resilience in FCERM policy has been avoided due to lack of consistent definitions.[86,87] Further challenges to integrating resilience into coastal management lie in accessing and integrating resilience metrics from different data sources.[88,89]

Box 3: Coastal Landfills
The UK has a legacy of coastal solid waste disposal sites which predate existing environmental legislation. There are at least 1700 historic landfills in the coastal plain.[99] Whilst only a small number of these are actively eroding, if not defended, at least 79 are threatened by erosion and >1200 have a 0.5% annual probability of coastal flooding in England alone, with potential consequences for human, aquatic and ecological health.[100,101] Although risk assessment methodologies exist,[102] a lack of funding means local authorities are constrained by the presence of waste and cannot apply more sustainable management approaches, such as managed realignment, which could provide sustainable coastal defence, habitat creation, carbon storage and maintain near shore sediment budgets.[99,103]

refresh to reflect changes in legislation, new information and knowledge.[90] SMPs set the preferred management approaches for each area over three time periods (2005-2025, 2026-2055, 2056-2100) from 4 strategic options:[79] 'hold the line' – maintain existing defences; 'managed realignment' of defences further inland; 'advance the line'; and 'no active intervention'.[91] SMPs may guide local coastal management, but are non-statutory and propose policy approaches without funding allocated.[1]

The Committee on Climate Change (CCC) stated that rates of managed realignment would need to be five-fold higher to meet the SMP's objective of 550km of coastline realigned by 2030.[1] Implementing SMPs would cost a total of £18-30 billion, and would not be cost beneficial for 149-185 km of England's coastline. For coastline designated as 'hold the line', 1,460km would not achieve the benefit cost ratio of recently funded projects.[1] In many cases, existing SMPs lack transparency and scientific currency in relation to climate change making them challenging to implement.[90] Legacy coastal landfill sites can also limit options for SMPs (Box 3). Between now and 2100, around 120,000-160,000 properties currently protected from coastal flooding could face uncertainty around the continuation of hold the line policies, and some may need to relocate.[92]

Building regulations, codes and planning law
In some sectors there is specific guidance on FCERM,[93] with design standards based on infrastructure type and level of risk aversion.[74,94] For example, the Office for Nuclear Regulation mandates sensitivity studies for site defences for nuclear power plants against a H++ scenario (Box 1),[95] and encourages an adaptive pathways management approach (Box 4).[93] Some sectors have adopted design codes incorporating high end SLR scenarios, but commentators suggest that the system of building regulations generally lacks clarity in addressing uncertain future SLR.[7] The EA provides guidance on addressing climate change risks for new developments,[94,96] and appraises FCERM plans for funding against their scenarios to maximise benefits of government funding.[96] The National Planning Policy Framework permits development in coastal flood risk areas if steered away from highest risk areas and made safe for its' lifetime without increasing risk elsewhere,[97] but predicting this is challenging (see changing coast section above). Development on the coastal flood plain may provide economic benefits but increases risks, with only high value areas meeting cost benefit criteria to receive central government funding for defence, which may result in entrenching inequality.[98]

Nature based solutions
Coastal habitats, including 80% of existing UK salt marsh, are protected under a range of national and international conservation designations.[3] Previously coastal habitat restoration has been required under the European Habitats directive, and is now required for sites designated as part of the National Nature Recovery Network.[104] Despite this, 15% of intertidal habitat has been lost in the UK since 1945.[3] With sufficient supply, intertidal habitats can trap sediment and grow vertically, moving landward as sea levels rise.[105,106] However, where habitats are constrained by hard defences (sea walls, levees) or development, they are unable to retreat. This process of 'coastal squeeze' may contribute to loss of coastal habitat under climate change.[107]

Increasingly, nature based solutions (NBS) are seen as a central pillar of coastal protection globally[108–110] and in the UK[111]. Broadly, NBS involve manipulating nature to address societal challenges.[112] Coastal NBS use the protective functions of coastal habitats in absorbing wave energy and storing flood waters to reduce impacts on the coast. The flood defence benefits provided by UK natural habitats have an estimated

Box 4: Adaptive Pathways Management
Adaptive pathways coastal management describe decision making approaches that account for uncertainty, which are incorporated into climate change adaptation standards.[113–116] It involves identifying a range of future adaptation scenarios, considering and evaluating the cost and effectiveness of management approaches for each scenario, alongside decision making triggers. A preferred pathway is selected and implemented, with monitoring, evaluation and learning to assess long term management options. This iterative approach allows options to be kept open while monitoring,[117–120] and to determine if a greater level of intervention is required (i.e. if sea level is rising faster than initially projected). It allows staggered investment, avoids costly future adaptation of defences, stranded assets, adaptation that increases risk elsewhere (maladaptation) or overinvestment in defences that cease to be cost effective.[121,122] It adapts to uncertain rates of SLR by triggering decisions earlier if it is faster than projected, and by leaving open options for future intervention (such as higher defences). Adaptive pathways approaches were developed for Thames Estuary 2100 plan,[114,123] and are now being implemented in the Humber Estuary and the Future Fens projects, as well as being applied internationally.[113]

value of £4.5bn.[3,124] The main focus of coastal NBS projects has been salt marsh restoration and beach replenishment, but offshore NBS are being explored. NBS projects can be used in conjunction with hard defences,[125–127] if SLR stays below 0.5m and habitats are not constrained by defences. The FCERM strategy committed to double the number of funded projects incorporating NBS,[128] but suggests they work best when implemented throughout catchments from source to sea.[129]

Saltmarsh

Typically, saltmarsh is the vegetated upper area of tidal flat.[130] It occurs in intertidal estuary environments with high sediment supply,[130] and has carbon storage [131–134] and other ecological benefits.[135–137] It can store flood water and build up with sea level, providing coastal flood risk mitigation.[138] In addition, the vegetation absorbs wave energy[138] and consolidates marsh substrate, making it resistant to surface erosion.[138] If sediment supply is sufficient, saltmarshes can grow and move inland with SLR.[139,140] Over 100 year time frames, incorporating saltmarsh can be more cost effective than 'hard' defences alone.[141]

In managed realignment (MR) schemes, an existing defence is breached to allow the area behind the sea wall to flood on high tide to create salt marsh.[142] To ensure successful functioning, MR schemes require careful design.[143] They may not deliver the same level of some ecological benefits such as differing drainage characteristics to their natural counterparts,[144] and monitoring criteria are ill defined.[145] Modelling suggests saltmarshes can reduce flood extents by 35% and damages by 37% in some estuaries[146] and a study comparing costs suggests they can be 2-5 times cheaper than submerged breakwaters,[109] but comparing their effectiveness is challenging.[109]

Beaches and Sand Dunes

Beach and dune systems create space between breaking waves and land, absorb wave energy and act as barriers to coastal flooding.[147–149] However, they are sensitive to sediment supply and measures that stop erosion elsewhere can lead to net loss of volume. Beach replenishment aims to maintain beach width/ volumes.[150,151] Removing barriers to allow sand dune migration inland (remobilisation) maintains their protective function with SLR.[148,152] In the UK, historic beach replenishment has involved 'beach fill' with sediment from nearshore dredging.[153] This has extended the operational life of some sea walls,[153] but concerns about ecological impacts[154] and sustainability[155] has led to more strategic approaches (Box 5).[151,156,157]

Reducing Offshore wave energy

Offshore subtidal, green infrastructure such as oyster reefs,[158-159] sea grass and kelp can absorb wave energy.[109,160,161] They trap sediment, grow with SLR and self-repair if damaged.[162] In the UK, sea grass has declined by 39% since the 1980s.[163] A coastal protection scheme incorporating oyster reef, sea grass and kelp beds has been included in the £150m Defra Flood and Coastal Resilience Innovation Programme.[164]

Social engagement with Coastal management

A key challenge for coastal management is reflecting community requirements.[165] Perceptions of benefits, costs and need for coastal management interventions, including MR,[166] can affect whether communities challenge authorities on management approaches.[167–169] People's relationships and sense of well-being in relation to coastal habitats is complex and requires local studies to design locally acceptable management strategies. However, more comprehensive frameworks for evaluating coastal management benefits and costs would be needed to capture intangible cultural value ecosystems (POSTbrief 34) hold for communities.[173] FCERM projects that are ethical and just, which engage with stakeholders early on,[174] and take account of local knowledge and perceptions,[175,176] can build acceptance for management interventions. Quantifying the cost of flooding and erosion has become more inclusive of costs beyond property loss, such as mental health.[177–179]

Metrics combining deprivation and vulnerability to coastal risk can be used alongside community knowledge to target management at socioeconomic flood disadvantage.[180,181]There is disproportionate vulnerability to coastal and other sources of flooding among those in affordable housing and socio-economically disadvantaged households[181], as well as gender [182] and age disparities.[183,184] Flooding from all sources disproportionately impacts ethnic minority households, those in 'post-industrial' towns and cities in the north[185] and rural communities.[186] The capacity of communities and individuals to take action (such as property level protection) is also unequal, with more affluent households and communities having more capacity to do so.[167] Insurance based solutions to distribute damages from coastal flood risk have limitations in uptake,[185,187] and availability. The £6,000 Coastal Erosion Assistance Grant for demolition and removal costs is the only compensation available for properties lost to erosion.[188] Nationally, a third of the 1.8 million people living in the coastal flood plain are within the top 20% most vulnerable neighbourhoods.[181] People whose homes have been flooded are approximately six times more likely to have poor mental health.[189] Adverse mental health effects and associated costs correlate with flood depth,[190] and put pressure on health and social care systems.[191]

Box 5: Bacton to Walcott Sand-scaping Scheme

The Bacton gas terminal on the North Norfolk coast is strategically important, supplying up to a third of the UK's natural gas.[170] The terminal and neighbouring villages are vulnerable to beach loss, resulting in wave overtopping of sea walls in the villages and erosion of soft cliffs adjacent to the plant; 10m of cliff eroded in the 2013 North Sea storm surge.[157] The Bacton to Walcott sand-scaping project was a partnership between the EA, North Norfolk District Council and gas terminal operators completed in 2019. With two thirds funding from gas terminal operators, the scheme cost £19 million.[157] Inspired by the Netherlands' 'ZandMotor', it placed 1.8 million cubic metres of sand on beaches between the gas terminal and Walcott. The design allows sand to be redistributed, to improve villages' flood defence while protecting the gas terminal.[157] The scheme is expected to extend the life of Bacton and Walcott's coastal defences by 15-20 years, allowing time for adaptation.

Monitoring of the scheme shows no overtopping of defences in Bacton and Walcott since completion; sediment has been retained near shore so the beach replenishes; despite early concerns, no adverse effects on wildlife have been observed.[171] There are ongoing projects into long term social and environmental impacts, but research suggests use of sand-scaping in England may be hindered by governance.[172]

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to James O'Neill for researching this briefing, to NERC for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Jonathan Wentworth.

1. the Committee on Climate Change (2018). Managing the coast in a changing climate. the Committee on Climate Change.
2. National Trust (2015). Shifting Shores.
3. Miles, R. *et al.* (2018). Sustainable Shores (Technical Report). Royal Society for the Protection of Birds.
4. HM Government (2020). National Risk Register - 2020 edition.
5. Edwards, T. (2017). Current and Future Impacts of Sea Level Rise on the UK. Government Office for Science, Foresight Evidence Review.
6. PIANC (2020). Climate Change Adaptation Planning for Ports and Inland Waterways.
7. IMechE (2019). Rising seas: the engineering challenge. Institute for Mechanical Engineers.
8. Environment Agency (2020). National Flood and Coastal Erosion Risk Management Strategy for England.
9. Haigh, I. D. *et al.* (2015). A user-friendly database of coastal flooding in the United Kingdom from 1915–2014. *Sci. Data*, Vol 2, 150021.
10. Wadey, M. P. *et al.* (2015). A comparison of the 31 January–1 February 1953 and 5–6 December 2013 coastal flood events around the UK. *Front. Mar. Sci.*, Vol 2,
11. Haigh, I. D. *et al.* (2020). Impacts of climate change on coastal flooding relevant to the coastal and marine environment around the UK. *MCCIP Sci. Rev.*,
12. Haigh, I. *et al.* (2017). Coastal flooding. *MCCIP Sci. Rev. 2017*, 7 pages. Marine Climate Change Impacts Partnership (MCCIP), Lowestoft, UK.
13. Hallegatte, S. *et al.* (2013). Future flood losses in major coastal cities. *Nat. Clim. Change*, Vol 3, 802–806.
14. Clark, P. U. *et al.* (2016). Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. *Nat. Clim. Change*, Vol 6, 360–369.
15. Oppenheimer, M. *et al.* (2019). Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. in *IPCC Special Report on the Oceans and Cryosphere in a Changing Climate*. 126. IPCC.
16. Wolf, J. *et al.* (2020). Impacts of climate change on storms and waves relevant to the coastal and marine environment around the UK. *MCCIP Sci. Rev. 2020*, 26 pages. Marine Climate Change Impacts Partnership (MCCIP), Lowestoft, UK.
17. McRobie, A. *et al.* (2005). The Big Flood: North Sea storm surge. *Philos. Trans. R. Soc. Math. Phys. Eng. Sci.*, Vol 363, 1263–1270.
18. van der Spek, A. J. F. (2018). The development of the tidal basins in the Dutch Wadden Sea until 2100: the impact of accelerated sea-level rise and subsidence on their sediment budget – a synthesis. *Neth. J. Geosci.*, Vol 97, 71–78.
19. Spencer, T. *et al.* (2016). Global coastal wetland change under sea-level rise and related stresses: The DIVA Wetland Change Model. *Glob. Planet. Change*, Vol 139, 15–30.
20. Bouwer, L. M. *et al.* (2007). Disaster Management: Confronting Disaster Losses. *Science*, Vol 318, 753–753.
21. Stevens, A. J. *et al.* (2016). Trends in reported flooding in the UK: 1884–2013. *Hydrol. Sci. J.*, Vol 61, 50–63.
22. Vousdoukas, M. I. *et al.* (2018). Understanding epistemic uncertainty in large-scale coastal flood risk assessment for present and future climates. Risk Assessment, Mitigation and Adaptation Strategies, Socioeconomic and Management Aspects.
23. Vousdoukas, M. I. *et al.* (2018). Climatic and socioeconomic controls of future coastal flood risk in Europe. *Nat. Clim. Change*, Vol 8, 776–780.
24. Sayers, P. *et al.* (2020). Next generation exploration of UK future flood risks: High resolution climate, population and adaptation futures. *Proc. FLOODrisk 2020 - 4th Eur. Conf. Flood Risk Manag.*, 6.
25. Brooks, S. M. *et al.* (2012). Shoreline retreat and sediment release in response to accelerating sea level rise: Measuring and modelling cliffline dynamics on the Suffolk Coast, UK. *Glob. Planet. Change*, Vol 80–81, 165–179.
26. Edwards, T. L. *et al.* (2021). Projected land ice contributions to twenty-first-century sea level rise. *Nature*, Vol 593, 74–82.
27. DeConto, R. M. *et al.* (2021). The Paris Climate Agreement and future sea-level rise from Antarctica. *Nature*, Vol 593, 83–89.
28. Howard, T. *et al.* (2019). Exploratory sea level projections for the UK to 2300. Environment Agency.
29. Palmer, M. *et al.* (2018). UKCP18 Marine report. Met Office.
30. Slingo, J. (2021). Latest Scientific Evidence for Observed and Projected Climate Change.
31. Hendry, A. *et al.* (2019). Assessing the characteristics and drivers of compound flooding events around the UK coast. *Hydrol. Earth Syst. Sci.*, Vol 23, 3117–3139.
32. Robins, P. E. *et al.* (2019). Changing Hydrology: A UK Perspective. in *Coasts and Estuaries*. 611–617. Elsevier.
33. Zhang, F. *et al.* (2019). Current reversals in a large tidal river. *Estuar. Coast. Shelf Sci.*, Vol 223, 74–84.
34. Kew, S. F. *et al.* (2013). The simultaneous occurrence of surge and discharge extremes for the Rhine delta. *Nat. Hazards Earth Syst. Sci.*, Vol 13, 2017–2029.
35. Ganguli, P. *et al.* (2019). Extreme Coastal Water Levels Exacerbate Fluvial Flood Hazards in Northwestern Europe. *Sci. Rep.*, Vol 9, 13165.
36. Ward, P. J. *et al.* (2018). Dependence between high sea-level and high river discharge increases flood hazard in global deltas and estuaries. *Environ. Res. Lett.*, Vol 13, 084012.
37. Arns, A. *et al.* (2020). Non-linear interaction modulates global extreme sea levels, coastal flood exposure, and impacts. *Nat. Commun.*, Vol 11, 1918.
38. Idier, D. *et al.* (2019). Interactions Between Mean Sea Level, Tide, Surge, Waves and Flooding: Mechanisms and Contributions to Sea Level Variations at the Coast. *Surv. Geophys.*, Vol 40, 1603–1630.
39. Bevacqua, E. *et al.* (2019). Higher probability of compound flooding from precipitation and storm surge in Europe under anthropogenic climate change. *Sci. Adv.*, Vol 5, eaaw5531.
40. Ganguli, P. *et al.* (2020). Projected Changes in Compound Flood Hazard From Riverine and Coastal Floods in Northwestern Europe. *Earths Future*, Vol 8,
41. Zscheischler, J. *et al.* (2017). Dependence of drivers affects risks associated with compound events. *Sci. Adv.*, Vol 3, e1700263.
42. Paprotny, D. *et al.* (2020). Pan-European hydrodynamic models and their ability to identify compound floods. *Nat. Hazards*, Vol 101, 933–957.
43. O'Neill, A. *et al.* (2018). Projected 21st Century Coastal Flooding in the Southern California Bight. Part 1: Development of the Third Generation CoSMoS Model. *J. Mar. Sci. Eng.*, Vol 6, 59.
44. Stokes, K. *et al.* (2021). Forecasting coastal overtopping at engineered and naturally defended coastlines. *Coast. Eng.*, Vol 164, 103827.
45. Christie, E. K. *et al.* (2018). Regional coastal flood risk assessment for a tidally dominant, natural coastal setting: North Norfolk, southern North Sea. *Coast. Eng.*, Vol 134, 177–190.
46. Rucker, C. A. *et al.* (2021). Downscaling of real-time coastal flooding predictions for decision support. *Nat. Hazards*, Vol 107, 1341–1369.
47. Huang, C.-J. *et al.* (2020). Operational monitoring and forecasting of wave run-up on seawalls. *Coast. Eng.*, Vol 161, 103750.

48. Chen, W. L. *et al.* (2021). A nonlinear perturbation study of a shoreface nourishment on a multiply barred beach. *Cont. Shelf Res.*, Vol 214, 104317.
49. McCall, R. T. *et al.* (2015). Modelling the morphodynamics of gravel beaches during storms with XBeach-G. *Coast. Eng.*, Vol 103, 52–66.
50. McCall, R. T. *et al.* (2014). Modelling storm hydrodynamics on gravel beaches with XBeach-G. *Coast. Eng.*, Vol 91, 231–250.
51. Dissanayake, P. *et al.* (2014). Modelling storm-induced beach/dune evolution: Sefton coast, Liverpool Bay, UK. *Mar. Geol.*, Vol 357, 225–242.
52. Brown, J. M. *et al.* (2020). WireWall - a new approach to measuring coastal wave hazard. National Oceanography Centre.
53. Dissanayake, P. *et al.* (2015). Comparison of storm cluster vs isolated event impacts on beach/dune morphodynamics. *Estuar. Coast. Shelf Sci.*, Vol 164, 301–312.
54. Moore, R. *et al.* (2015). Cliff instability and erosion management in England and Wales. *J. Coast. Conserv.*, Vol 19, 771–784.
55. Burvingt, O. *et al.* (2017). Classification of beach response to extreme storms. *Geomorphology*, Vol 295, 722–737.
56. Masselink, G. *et al.* (2016). The extreme 2013/2014 winter storms: hydrodynamic forcing and coastal response along the southwest coast of England. *Earth Surf. Process. Landf.*, Vol 41, 378–391.
57. Brooks, S. M. *et al.* (2016). Reconstructing and understanding the impacts of storms and surges, southern North Sea. *Earth Surf. Process. Landf.*, Vol 41, 855–864.
58. Masselink, G. *et al.* (2020). Impacts of climate change on coastal geomorphology and coastal erosion relevant to the coastal and marine environment around the UK. *MCCIP Sci. Rev. 2020*, 32 pages. Marine Climate Change Impacts Partnership (MCCIP), Lowestoft, UK.
59. Pollard, J. *et al.* (2019). The interactive relationship between coastal erosion and flood risk. *Prog. Phys. Geogr. Earth Environ.*, Vol 43, 574–585.
60. Lim, M. *et al.* (2011). Quantifying the Controls and Influence of Tide and Wave Impacts on Coastal Rock Cliff Erosion. *J. Coast. Res.*, Vol 27, 46–56.
61. Karunarathna, H. *et al.* (2018). Multi-timescale morphological modelling of a dune-fronted sandy beach. *Coast. Eng.*, Vol 136, 161–171.
62. Baar, A. W. *et al.* (2019). Critical dependence of morphodynamic models of fluvial and tidal systems on empirical downslope sediment transport. *Nat. Commun.*, Vol 10, 4903.
63. Lyddon, C. E. *et al.* (2019). Quantification of the Uncertainty in Coastal Storm Hazard Predictions Due to Wave-Current Interaction and Wind Forcing. *Geophys. Res. Lett.*, Vol 46, 14576–14585.
64. Forster, J. *et al.* (2020). Mapping feasibilities of greenhouse gas removal: Key issues, gaps and opening up assessments. *Glob. Environ. Change*, Vol 63, 102073.
65. Channel Coastal Observatory (2021). National Network of Regional coastal monitoring programmes.
66. Brown, J. M. *et al.* (2016). The effectiveness of beach mega-nourishment, assessed over three management epochs. *J. Environ. Manage.*, Vol 184, 400–408.
67. Prime, T. *et al.* (2018). Protecting Energy Infrastructure against the Uncertainty of Future Climate Change: A Real Options Approach. *J. Ocean Coast. Econ.*, Vol 5,
68. Boyes, S. *et al.* (2017). The East Riding Coastline: Past, Present and Future. University of Hull.
69. Luijendijk, A. *et al.* (2018). The State of the World's Beaches. *Sci. Rep.*, Vol 8, 6641.
70. NOC (2021). Coastal REsistance: Alerts and Monitoring Technologies (CreamT).
71. Environment Agency (2015). Flood and coastal erosion: risk management authorities.
72. HM Government (1949). Coast Protection Act.
73. National Infrastructure Commission (2020). Anticipate, React, Recover: Resilient infrastructure systems.
74. National Infrastructure Commission (2018). National Infrastructure Assessment. 163.
75. Ipsos MORI (2018). National Infrastrucutre Commission Phase 2: public research.
76. Priestley, S. (2017). Flood risk management and funding. House of Commons Library.
77. The Environment Agency (2021). A review of skills and guidance in flood and coastal risk management benefit cost assessment - appendix B. the Environment Agency.
78. Penning-Rowsell, E. *et al.* (2014). Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal. Routledge.
79. Cooper, N. J. *et al.* (2002). Shoreline management plans: a national review and engineering perspective. *Proc. Inst. Civ. Eng. - Water Marit. Eng.*, Vol 154, 221–228.
80. Townend, B. I. H. *et al.* (2021). Operationalising coastal resilience to flood and erosion hazard: A demonstration for England. *Sci. Total Environ.*, Vol 783, 146880.
81. Masselink, G. *et al.* (2019). Defining Coastal Resilience. *Water*, Vol 11, 2587.
82. Chaffin, B. C. *et al.* (2018). Social-ecological resilience and geomorphic systems. *Geomorphology*, Vol 305, 221–230.
83. Flood, S. *et al.* (2014). The rise of resilience: Evolution of a new concept in coastal planning in Ireland and the US. *Ocean Coast. Manag.*, Vol 102, 19–31.
84. Tooth, S. (2018). The geomorphology of wetlands in drylands: Resilience, nonresilience, or …? *Geomorphology*, Vol 305, 33–48.
85. National Infrastructure Commission (2020). Anticipate, React, Recover: Resilient infrastructure systems.
86. Eustice, G. (2020). George Eustice repsonse to NIC work on resilience.
87. Twigger-Ross, C. *et al.* (2020). Evidence Review of the Concept of Flood Resilience. DEFRA.
88. Waterman, L. *et al.* (2021). A Mixed-Methods Investigation into Barriers for Sharing Geospatial and Resilience Flood Data in the UK. *Water*, Vol 13, 1235.
89. Lazarus, E. *et al.* (2020). The UK needs an open data portal dedicated to coastal flood and erosion hazard risk and resilience. Geographic Information Sciences.
90. Ballinger, R. C. *et al.* (2020). Shoreline management plans in England and Wales: A scientific and transparent process? *Mar. Policy*, Vol 111, S0308597X17301422.
91. Environment Agency (2021). National Coastal Erosion Risk Mapping. *National Erosion Risk Mapping*.
92. Sayers, P. *et al.* (In Review). Responding to climate change around England's coast - The scale of the transformational challenge. *J. Ocean Coast. Manag.*,
93. Office for Nuclear Regulation (2020). Use of UK Climate Projections 2018 (UKCP18) - Position Statement. ONR.
94. Environment Agency (2020). Flood risk assessments: climate change allowances.
95. Office for Nuclear Regulation (2018). Coastal Flood Hazards. ONR.
96. Environment Agency (2020). Flood and coastal risk projects, schemes and strategies: climate change allowances.
97. MHCLG (2019). National Planning Policy Framework.
98. Cheshire, P. *et al.* (2002). The welfare economics of land use planning. *J. Urban Econ.*, Vol 52, 242–269.
99. Beaven, R. P. *et al.* (2020). Future challenges of coastal landfills exacerbated by sea level rise. *Waste Manag.*, Vol 105, 92–101.

100. Brand, J. H. *et al.* (2019). Potential contamination of the coastal zone by eroding historic landfills. *Mar. Pollut. Bull.*, Vol 146, 282–291.
101. Brand, J. H. *et al.* (2018). Potential pollution risks of historic landfills on low-lying coasts and estuaries: Potential pollution risks of historic landfills. *Wiley Interdiscip. Rev. Water*, Vol 5, e1264.
102. Brand, J. H. *et al.* (2018). Risk screening assessment for ranking historic coastal landfills by pollution risk. *Anthr. Coasts*, Vol 1, 44–61.
103. Nicholls, R. J. *et al.* (2020). Coastal Landfills, Rising Sea Levels and Shoreline Management: A Challenge for the 21st Century. in *Coastal Management 2019*. 391–404. ICE Publishing.
104. Defra (2018). A Green Future: Our 25 Year Plan to Improve the Environment. HM Government.
105. van der Wal, D. *et al.* (2004). Patterns, rates and possible causes of saltmarsh erosion in the Greater Thames area (UK). *Geomorphology*, Vol 61, 373–391.
106. Cundy, A. B. *et al.* (1996). Sediment Accretion and Recent Sea-level Rise in the Solent, Southern England: Inferences from Radiometric and Geochemical Studies. *Estuar. Coast. Shelf Sci.*, Vol 43, 449–467.
107. Pontee, N. (2013). Defining coastal squeeze: A discussion. *Ocean Coast. Manag.*, Vol 84, 204–207.
108. Chowdhury, M. S. N. *et al.* (2019). Oyster breakwater reefs promote adjacent mudflat stability and salt marsh growth in a monsoon dominated subtropical coast. *Sci. Rep.*, Vol 9, 8549.
109. Narayan, S. *et al.* (2016). The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences. *PLOS ONE*, Vol 11, e0154735.
110. European Commission (2021). Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change. European Commission.
111. Stafford, R. *et al.* (2021). Nature-based Solutions for Climate Change in the UK: A Report by the British Ecological Society. British Ecological Society.
112. (2016). Nature-based solutions to address global societal challenges. IUCN International Union for Conservation of Nature.
113. Allison, R. *et al.* (2021). Literature review on an adaptive approach to flood and coastal risk management.
114. McGahey, C. *et al.* (2008). Long term planning – Robust strategic decision making in the face of gross uncertainty (tools and application to the Thames). in
115. BSI BS 8631:2021: Adaptation to climate change. Using adaptation pathways for decision making. Guide.
116. ISO (2019). ISO 14090:2019.
117. Haasnoot, M. *et al.* (2018). Designing a monitoring system to detect signals to adapt to uncertain climate change. *Glob. Environ. Change*, Vol 52, 273–285.
118. Hermans, L. M. *et al.* (2017). Designing monitoring arrangements for collaborative learning about adaptation pathways. *Environ. Sci. Policy*, Vol 69, 29–38.
119. Haasnoot, M. *et al.* (2019). Generic adaptation pathways for coastal archetypes under uncertain sea-level rise. *Environ. Res. Commun.*, Vol 1, 071006.
120. Haasnoot, M. *et al.* (2019). Dynamic Adaptive Policy Pathways (DAPP). in *Decision Making under Deep Uncertainty*. (eds. Marchau, V. A. W. J. et al.) 71–92. Springer International Publishing.
121. Haasnoot, M. *et al.* (2020). Investments under non-stationarity: economic evaluation of adaptation pathways. *Clim. Change*, Vol 161, 451–463.
122. Barnett, J. *et al.* (2013). Minimising the risk of maladaptation: a framework for analysis. in *Climate Adaptation Futures*. (eds. Palutikof, J. et al.) 87–93. John Wiley & Sons.
123. Ranger, N. *et al.* (2013). Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project. *EURO J. Decis. Process.*, Vol 1, 233–262.
124. Beaumont, N. J. *et al.* (2014). The value of carbon sequestration and storage in coastal habitats. *Estuar. Coast. Shelf Sci.*, Vol 137, 32–40.
125. Debele, S. E. *et al.* (2019). Nature-based solutions for hydro-meteorological hazards: Revised concepts, classification schemes and databases. *Environ. Res.*, Vol 179, 108799.
126. Gómez Martín, E. *et al.* (2020). An operationalized classification of Nature Based Solutions for water-related hazards: From theory to practice. *Ecol. Econ.*, Vol 167, 106460.
127. Du, S. *et al.* (2020). Hard or soft flood adaptation? Advantages of a hybrid strategy for Shanghai. *Glob. Environ. Change*, Vol 61, 102037.
128. HM Government (2020). Flood and Coastal Erosion Risk Management Policy Statement. HM Government.
129. The Environment Agency (2021). FCERM Strategy Action Plan 2021. 36.
130. Allen, J. (2000). Morphodynamics of Holocene salt marshes: a review sketch from the Atlantic and Southern North Sea coasts of Europe. *Quat. Sci. Rev.*, Vol 19, 1155–1231.
131. Burden, A. *et al.* (2019). Effect of restoration on saltmarsh carbon accumulation in Eastern England. *Biol. Lett.*, Vol 15, 20180773.
132. Burden, A. *et al.* (2013). Carbon sequestration and biogeochemical cycling in a saltmarsh subject to coastal managed realignment. *Estuar. Coast. Shelf Sci.*, Vol 120, 12–20.
133. Ford, H. *et al.* (2012). Methane, carbon dioxide and nitrous oxide fluxes from a temperate salt marsh: Grazing management does not alter Global Warming Potential. *Estuar. Coast. Shelf Sci.*, Vol 113, 182–191.
134. Himes-Cornell, A. *et al.* (2018). Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. *Ecosyst. Serv.*, Vol 30, 36–48.
135. Morris, R. L. *et al.* (2018). From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. *Glob. Change Biol.*, Vol 24, 1827–1842.
136. Kneib, R. T. (1997). Early Life Stages of Resident Nekton in Intertidal Marshes. *Estuaries*, Vol 20, 214.
137. Temmerman, S. *et al.* (2013). Ecosystem-based coastal defence in the face of global change. *Nature*, Vol 504, 79–83.
138. Möller, I. *et al.* (2014). Wave attenuation over coastal salt marshes under storm surge conditions. *Nat. Geosci.*, Vol 7, 727–731.
139. Kirwan, M. L. *et al.* (2016). Overestimation of marsh vulnerability to sea level rise. *Nat. Clim. Change*, Vol 6, 253–260.
140. Schuerch, M. *et al.* (2018). Future response of global coastal wetlands to sea-level rise. *Nature*, Vol 561, 231–234.
141. Vuik, V. *et al.* (2019). Salt marshes for flood risk reduction: Quantifying long-term effectiveness and life-cycle costs. *Ocean Coast. Manag.*, Vol 171, 96–110.
142. ABPmer (2021). The Online Managed Realignment Guide.
143. Kiesel, J. *et al.* (2020). Effective design of managed realignment schemes can reduce coastal flood risks. *Estuar. Coast. Shelf Sci.*, Vol 242, 106844.
144. Tempest, J. A. *et al.* (2015). Modified sediments and subsurface hydrology in natural and recreated salt marshes and implications for delivery of ecosystem services: Hydrological functioning in restored salt marshes. *Hydrol. Process.*, Vol 29, 2346–2357.
145. Brady, A. F. *et al.* (2017). How do we know if managed realignment for coastal habitat compensation is

successful? Insights from the implementation of the EU Birds and Habitats Directive in England. *Ocean Coast. Manag.*, Vol 143, 164–174.
146. Fairchild, T. *et al.* (2021). Coastal wetlands mitigate storm flooding and associated costs in estuaries.
147. Hanley, M. E. *et al.* (2014). Shifting sands? Coastal protection by sand banks, beaches and dunes. *Coast. Eng.*, Vol 87, 136–146.
148. Pye, K. (2007). Sand dune processes and management for flood and coastal defence. 18.
149. Laso Bayas, J. C. *et al.* (2013). Tsunami in the Seychelles: Assessing mitigation mechanisms. *Ocean Coast. Manag.*, Vol 86, 42–52.
150. Moreno, L. J. *et al.* (2021). Beach Nourishment: A 21st Century Review. *J. Mar. Sci. Eng.*, Vol 9, 499.
151. Stive, M. J. F. *et al.* (2013). A New Alternative to Saving Our Beaches from Sea-Level Rise: The Sand Engine. *J. Coast. Res.*, Vol 290, 1001–1008.
152. Laporte-Fauret, Q. *et al.* (2021). Morphological and ecological responses of a managed coastal sand dune to experimental notches. *Sci. Total Environ.*, Vol 782, 146813.
153. Hanson, H. *et al.* (2002). Beach nourishment projects, practices, and objectives—a European overview. *Coast. Eng.*, Vol 47, 81–111.
154. Peterson, C. H. *et al.* (2006). Exploiting beach filling as an unaffordable experiment: Benthic intertidal impacts propagating upwards to shorebirds. *J. Exp. Mar. Biol. Ecol.*, Vol 338, 205–221.
155. Parkinson, R. W. *et al.* (2018). Beach nourishment is not a sustainable strategy to mitigate climate change. *Estuar. Coast. Shelf Sci.*, Vol 212, 203–209.
156. Escudero, M. *et al.* (2020). Micro Sand Engine Beach Stabilization Strategy at Puerto Morelos, Mexico. *J. Mar. Sci. Eng.*, Vol 8, 247.
157. Clipsham, V. *et al.* (2021). Bacton to Walcott sandscaping, UK: a softer approach to coastal management. *Proc. Inst. Civ. Eng. - Civ. Eng.*, Vol 174, 49–56.
158. Borsje, B. W. *et al.* (2011). How ecological engineering can serve in coastal protection. *Ecol. Eng.*, Vol 37, 113–122.
159. Morris, R. L. *et al.* (2019). The application of oyster reefs in shoreline protection: Are we over-engineering for an ecosystem engineer? *J. Appl. Ecol.*, Vol 56, 1703–1711.
160. Morris, R. L. *et al.* (2019). Kelp beds as coastal protection: wave attenuation of Ecklonia radiata in a shallow coastal bay. *Ann. Bot.*, mcz127.
161. Mork, M. (1996). The effect of kelp in wave damping. *Sarsia*, Vol 80, 323–327.
162. Gittman, R. K. *et al.* (2014). Marshes with and without sills protect estuarine shorelines from erosion better than bulkheads during a Category 1 hurricane. *Ocean Coast. Manag.*, Vol 102, 94–102.
163. Green, A. E. *et al.* (2021). Historical Analysis Exposes Catastrophic Seagrass Loss for the United Kingdom. *Front. Plant Sci.*, Vol 12, 629962.
164. HM Government (2021). Innovative projects to protect against flooding selected.
165. Kelly, R. *et al.* (2019). Community engagement on climate adaptation - and evidence review. Environment Agency.
166. McKinley, E. *et al.* (2020). Forgotten landscapes: Public attitudes and perceptions of coastal saltmarshes. *Ocean Coast. Manag.*, Vol 187, 105117.
167. Forrest, S. A. *et al.* (2021). Emerging citizen contributions, roles and interactions with public authorities in Dutch pluvial flood risk management. *Int. J. Water Resour. Dev.*, Vol 37, 1–23.
168. Ipswich Star (2004). Lobby Group Celebrates. *Ipswich Star*.
169. CCAG (2021). Coastal Concern Action Group. *Happisburgh Coastal Concern Action Group*.
170. Shell (2021). About Bacton Gas Plant.
171. BBC (2019). RSPB warns Bacton cliffs netting 'could kill' birds.
172. Vikolainen, V. *et al.* (2017). Governance context for coastal innovations in England: The case of Sandscaping in North Norfolk. *Ocean Coast. Manag.*, Vol 145, 82–93.
173. Rendón, O. R. *et al.* (2019). A framework linking ecosystem services and human well-being: Saltmarsh as a case study. *People Nat.*, Vol 1, 486–496.
174. Creed, R. *et al.* (2018). Moving towards sustainable coasts: A critical evaluation of a stakeholder engagement group in successfully delivering the mechanism of adaptive management. *Mar. Policy*, Vol 90, 184–193.
175. Thomas, M. *et al.* (2015). Mental models of sea-level change: A mixed methods analysis on the Severn Estuary, UK. *Glob. Environ. Change*, Vol 33, 71–82.
176. Haughton, G. *et al.* (2015). In search of 'lost' knowledge and outsourced expertise in flood risk management. *Trans. Inst. Br. Geogr.*, Vol 40, 375–386.
177. Waite, T. D. *et al.* (2017). The English national cohort study of flooding and health: cross-sectional analysis of mental health outcomes at year one. *BMC Public Health*, Vol 17, 129.
178. Mulchandani, R. *et al.* (2020). The English National Cohort Study of Flooding & Health: psychological morbidity at three years of follow up. *BMC Public Health*, Vol 20, 321.
179. Yesodharan, R. *et al.* (2021). The Lived Experience of Victims of Catastrophic Coastal Erosion: A cycle of impact, consequence and recovery. *Sultan Qaboos Univ. Med. J. SQUMJ*, Vol 21, e94-102.
180. National Flood Forum (2017). Testing approaches to flood resilience for disadvantaged areas.
181. Sayers, P. B. *et al.* (2017). Present and future flood vulnerability, risk and disadvantage: A UK scale assessment. A report for the Joseph Rowntree Foundation published by Sayers and Partners LLP.
182. Lowe, D. *et al.* (2013). Factors Increasing Vulnerability to Health Effects before, during and after Floods. *Int. J. Environ. Res. Public. Health*, Vol 10, 7015–7067.
183. Tapsell, S. M. *et al.* (2002). Vulnerability to flooding: health and social dimensions. *Philos. Trans. R. Soc. Lond. Ser. Math. Phys. Eng. Sci.*, Vol 360, 1511–1525.
184. Walker, G. *et al.* (2011). Flood risk, vulnerability and environmental justice: Evidence and evaluation of inequality in a UK context. *Crit. Soc. Policy*, Vol 31, 216–240.
185. Sayers, P. B. *et al.* (2020). Flood disadvantage: socially vulnerable and ethnic communities.
186. Begg, C. *et al.* (2015). Localism and flood risk management in England: the creation of new inequalities? *Environ. Plan. C Gov. Policy*, Vol 33, 685–702.
187. Sayers, P. *et al.* (2016). The analysis of future flood risk in the UK using the Future Flood Explorer. *E3S Web Conf.*, Vol 7, 21005.
188. Defra (2020). How are we working to tackle coastal erosion?
189. Public Health England (2020). The English National Study of Flooding and Health, Summary of the evidence generated to date. Public Health England.
190. Priest, S. *et al.* (2020). A method for monetising the mental health costs of flooding. Environment Agency.
191. Curtis, S. *et al.* (2017). Impact of extreme weather events and climate change for health and social care systems. *Environ. Health*, Vol 16, 128.