APPENDIX D: **INDIVIDUAL ADAPTATION MEASURES**

Contents

D.1 Introduction 2
D.2 Coastal and river flood defence and control infrastructure 3
D.3 Shoreline management 6
D.4 Catchment management 8
D.5 Urban management 10
D.6 Spatial planning (Development control) 12
D.7 Receptor (property – new and existing - and infrastructure) level measures 13
D.8 Forecasting and warning 15
D.9 Insurance 17
D.10 Governance and organisational arrangements 18
D.11 References 18

D.1 Introduction

Nine individual Adaptation Measures (AMs) that address the three components of risk (set out in Chapter 6 of the Main report) are considered (Figure 1) with each Adaptation Measure assigned three levels of ambition as follows:

- **Current**: assuming the measure **continues** to be implemented as effectively as experienced in the recent past (i.e. achieving the same outcomes as in recent years). This links to the 'current objectives' portfolio (Current Level of Adaptation – CLA)
- **Higher:** assuming the measure is implemented **more** effectively than in the recent past. This links to the 'current objectives+' portfolio (Enhanced Whole System adaptation – EWS)
- **Lower:** assuming the measure is implemented **less** effectively than in the recent past. This links to the 'no further action' portfolio (Reduced Whole System adaptation – RWS)

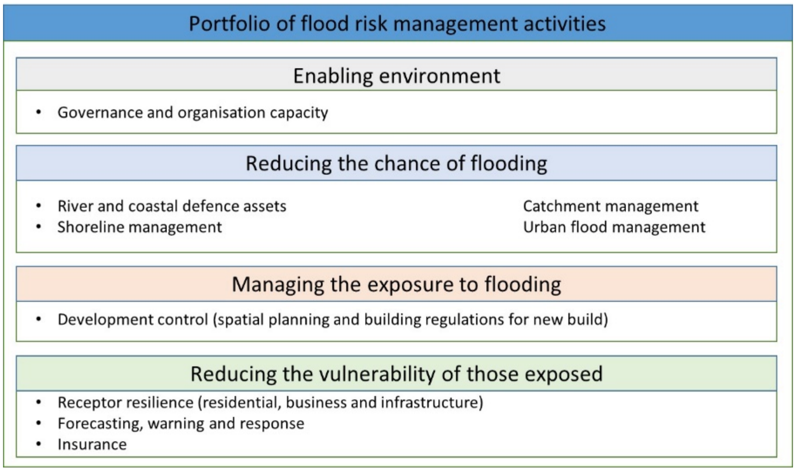

Figure 1 Portfolio of individual Adaptation Measures

The evidence used to determine the degree of effectiveness builds on analysis for CCRA2 (Sayers et al, 2015), the JRF (Sayers et al., 2016) and the NIC (Sayers et al., 2018) together with discussion of adaptation measures with national flood lead stakeholders.

Note:

A consistent representation of each measure is used throughout the UK unless there is compelling evidence to do otherwise (e.g. for example as is the case for the implementation of SuDS) and differential implementation is possible within the context of the project resources.

Note: Characterization of social flood vulnerability. The Neighbourhood Flood Vulnerability Index (NFVI, introduced in the Main Report) is used to better differentiate future risk by more and less socially vulnerable communities and, where appropriate, differentiate the effectiveness of individual adaptation measures. Where a lever is differentiated by NFVI this is highlighted.

D.2 Coastal and river flood defence and control infrastructure

Representation within the FFE

Within the FFE defence standards and condition reduce (or, in some locations, increase) with climate change until a minimum standard is reached (defined as a percentage of the present day standard) at which point it is raised to new standard (again defined as a percentage of the present day standard). This process is illustrated in Figure 2. This assessment operates at an aggregated scale based on the representative standard of protection afforded to an area (rSOP- Figure 3) and the associated representation condition grade of the defences (rCg – reflecting the condition of the defence and hence its chance of breach under load). The settings applied to both the rSOP and rCg within the lower, central and higher adaptation future are summarized in Table 1. These are based on previous studies (e.g. reflecting the NIC finding of the likely efficiency of protecting large urban areas with raised defences within a higher adaptation future) and review by policy leads.

Note:

The FFE has been significantly improved for CCRA3 compared to CCRA2. Primarily this includes improved defence datasets in England and Wales (although gaps remain) and greater control on where and how flood defences are implemented in each adaptation future. In Scotland and Northern Ireland the flood defence data is much less complete.

CCRA3 continues to adopt a scenario approach to defence improvements rather than a direct benefit cost assumption to investment in defences.

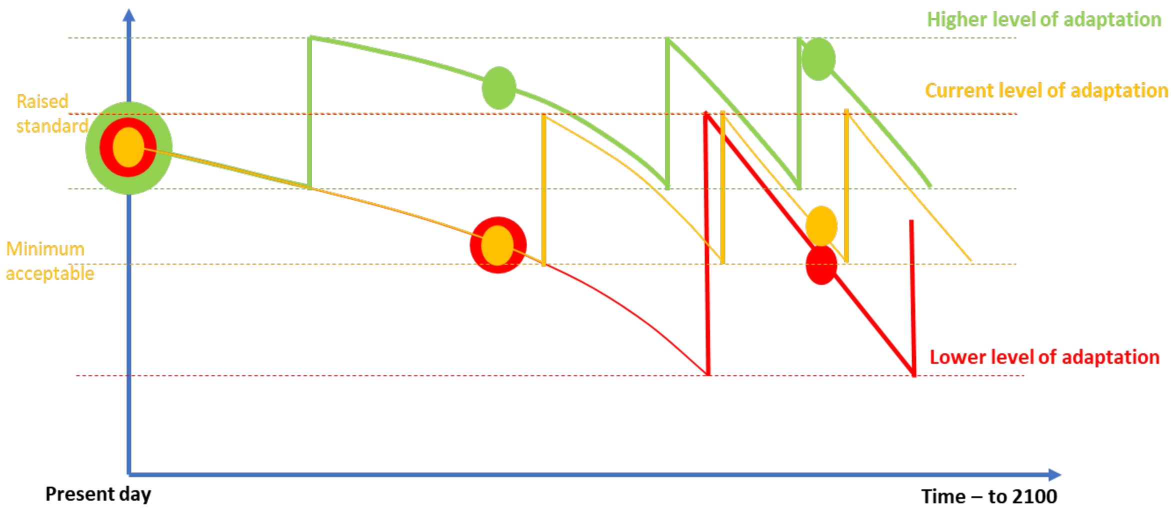

Figure 2 The representation of defence standards

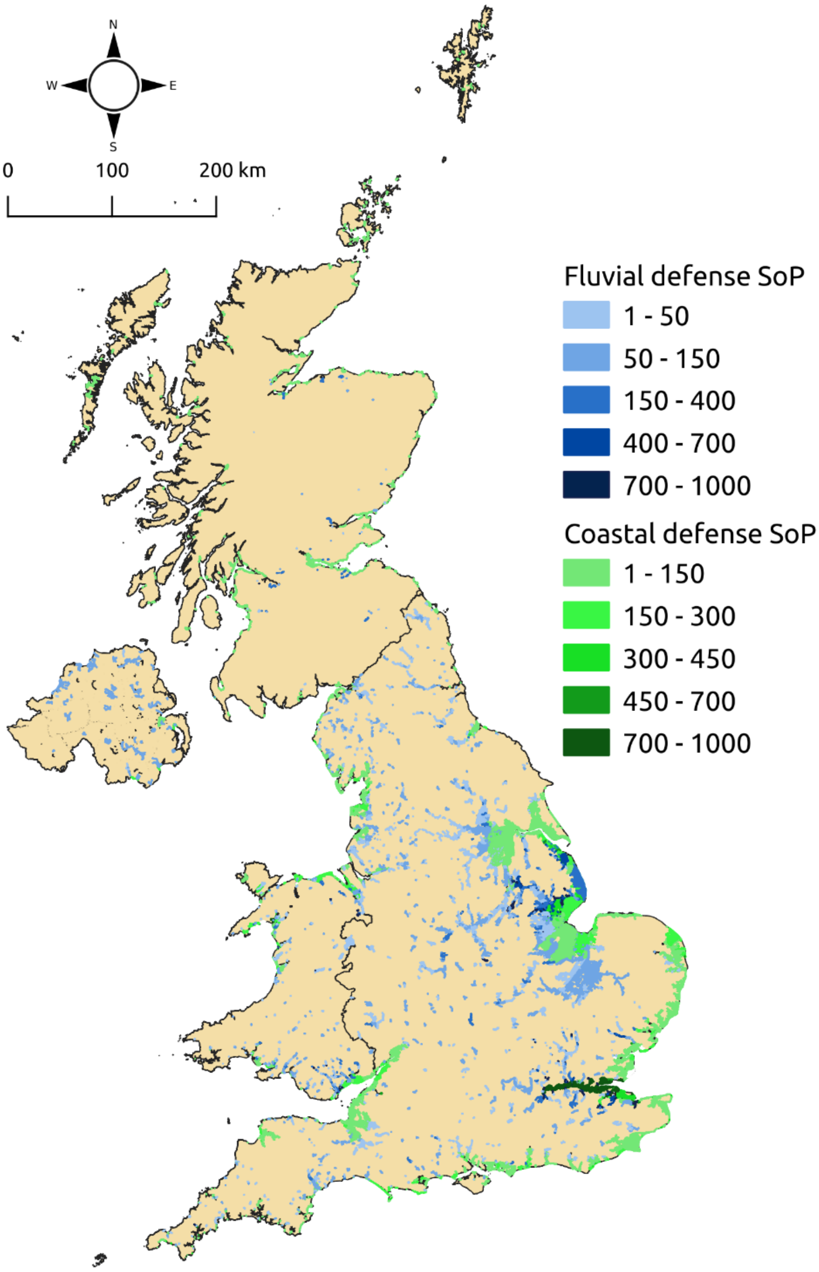

Figure 3 Present day defence standards (representative standards shown)

Table 1 Adaptation measure: Flood defence and control infrastructure

Future changes in standard of protection as a function of settlement type and present-day standards (values show the allowable future standard as a proportion of the present-day standard). This is a summary of the settings – more detail can be provided on request.

	Lower				Current				Higher			
Present day standard (years)	Urban	rural	Urban	rural	Urban	rural	Urban	rural	Urban	rural	Urban	rural
0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
25	0.5	0.5	0.5	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1	0.75	1	0.75
100	0.75	0.75	0.75	0.75	1	1	1	1	1	1	1	1
500	1	1	1	1	1	1	1	1	1	1	1	1
1000	1	1	1	1	1	1	1	1	1	1	1	1
Minimum standards												
	None				100	in urban majors (where present day defences exist)			100	in urban majors (all areas including present day undefended)		
									75	in urban towns and cities (where significant defences already exist))		
									75	in those rural towns that have the highest present-day standards		

Future changes in condition grade (an indicator of the potential for infrastructure to fail)

rCg today	**Change in Condition Grade (Cg)**		
	Lower	*Current*	*Higher*
1	*1*	*1*	1
2	*2*	*2*	2
3	*4*	*3*	3
4	*5*	*4*	3
5	*6*	*6*	6

D.3 Shoreline management

Representation within the FFE

Within the FFE, realignment influences the standard of protection afforded. It is assumed that realignment provides a buffer to the backshore defences and contributes sediment to the nearshore and enables a more natural pattern of drift. These morphological processes help maintain beach performance and they improve the effective standard afforded by flood defences where they exist. This linkage is difficult to represent at a localized scale here. Instead it is assumed to influence the standards regionally (e.g. within the SMP area). In the absence of a more refined analysis or strong evidence, it is assumed here that this connection is relatively weak and varies by storm return period (with a greater impact on more frequent storms and less on more extreme storms) - see Table 2.

Note: CCRA3 refines the spatial scale on the assessment of realignment to reflect the aspirations in individual SMP areas. The representation of impact of realignment on coastal defence standards within the FFE remains unchanged from CCRA2.

Table 2 Adaptation measure: Summary of coastal realignment

% implementation of statement realignment policies

Adaptation measure	2020s			2050s			2080s		
	Lower	*Current*	*Higher*	*Lower*	*Current*	*Higher*	*Lower*	*Current*	*Higher*
% implementation of realignment policies/opportunities									
Across the UK	*2%*	*5%*	*20%*	*2%*	*20%*	*50%*	*2%*	*40%*	*100%*

Note: In Scotland and Northern Ireland much of the coast comes under a no active intervention policy with little managed realignment. Therefore a single of 6% of the coastline (based on a review of Scottish policies by SEPA – email April 2020)

Proportion of coastline with managed under a policy of no active intervention or managed realignment (or equivalent) given the 'current' level of adaptation ambition

% coastline realigned in recent years (based on England 1990-2016)	***Proportion of coast managed under a no active interventionl or managed realignment policy***		
	2020s	*2050s*	*2080s*
2%	*5%*	*20%*	*40%*
England			
01 - Scottish Border to River Tyne	0.05	0.20	0.28
02 - The Tyne to Flamborough Head	0.05	0.07	0.07
03 - Flamborough Head to Gibraltar Point	0.03	0.00	0.00
04 - Gibraltar Point to Hunstanton	0.00	0.00	0.00
05 - Hunstanton to Kelling Hard	0.05	0.20	0.30
06 - Kelling Hard to Lowestoft	0.05	0.20	0.40
07 - Lowestoft to Felixstowe	0.05	0.20	0.25
08 - Essex and South Suffolk	0.05	0.15	0.14
09 - River Medway and Swale Estuary	0.05	0.20	0.30
10 - Isle of Grain to South Foreland	0.04	0.20	0.30
11 - South Foreland to Beachy Head	0.05	0.08	0.19
12 - Beachy Head to Selsey Bill	0.05	0.10	0.15
13 - Selsey Bill to Hurst Spit	0.02	0.02	0.01
14 - Isle of White	0.00	0.01	0.03
15 - Hurst Spit to Durlston Head	0.05	0.17	0.18
16 - Durlston Head to Rame Head	0.05	0.09	0.07
17 - Rame Head to Hartland Point	0.05	0.12	0.11
18 - Hartland Point to Anchor Head	0.03	0.10	0.08
19 - Anchor Head to Lavernock Point	0.05	0.14	0.16
22 - Great Ormes Head to Scotland	0.05	0.20	0.21
Wales			
19 - Anchor Head to Lavernock Point	0.05	0.14	0.16
20 - Lavernock Point to St Ann's Head	0.03	0.10	0.08
21 - St Ann's Head to Gread Ormes Head	0.05	0.12	0.11
22 - Great Ormes Head to Scotland	0.05	0.20	0.21
Scotland			
East	0.06	0.06	0.06
North	0.06	0.06	0.06
North-west	0.06	0.06	0.06
Northern Ireland			
Northern Ireland	0.06	0.06	0.06

% of the climate change induced reduction in the standard of protection avoided for each additional 2% of the coast realignment

rSOP today in coastal areas only (years)	**All adaptation futures**		
	2020s	2050s	2080s
5	2%	2%	2%
50	2%	2%	2%
100	1%	1%	1%
200	0%	0%	0%

D.4 Catchment management

Representation within the FFE

To reflect the influence of catchment management, three aspects are considered:

- **Catchment potential:** The impact on flood flows is highest in those catchments with the greatest potential (as defined, broadly, by the available mapping from national leads) and reduces in those catchments with moderate or low potential. This potential is assumed here to be defined by the proportion of the catchment area considered to represent an NFM opportunity. This potential remains unchanged across all adaptation futures. In those catchments with the highest potential the impact on the flow is highest (Table 3)
- **Scale of NFM ambition:** The degree to which the potential opportunity for NFM is translated to on-the-ground measures will, in part, vary according to the opportunity for alternative uses of the land. In catchments with a high proportion of the Best and Most Versatile (BMV) land there is likely to be a lower opportunity to use NFM than elsewhere because of competition from other productive uses of the land. A limit is therefore placed on the percentage of each class of BMV land that can be used for NFM purposes. This limit is differentiated by adaptation scenarios and given in Table 3.
- **Impact across different return period flows:** The change in flood flows is assumed to be function of the catchment area used for NFM (a combination of the above two aspects) and their effectiveness. It is assumed here that the maximum reduction in flow that can be achieved by NFM (if all potential opportunities within a catchment are taken up) is 10% during a 1in50 year event and up to twice this in the 2-year event. These maximum values remain unchanged across the adaptation futures (as they represent maximum potential).

Note: CCRA3 significantly improves the representation of catchment management compared to CCRA2. The approach extends the method recently used in the National Infrastructure Assessment (Sayers et al., 2018). The confidence in the performance of NFM measures to reduce downstream flood flows remains however an area of active research. An improved understanding is expected in coming years as three on-going NERC programmes develop new evidence and the results of pilot studies are analysed (from across Wales, Scotland and England). This does not imply a lack of confidence in catchment measures – they are accepted as beneficial, but it remains difficult to determine by how much.

Table 3 Adaptation measure: Catchment management

Impact on flow is highest in those catchments with the highest potential

Catchment potential: 1:50 year event reduction in peak	Percentage reduction in peak runoff by this year			
	Present day	2020s	2050s	2080s
Run-off management features				
15% highest NFM woodland potential by catchment area	0%	3%	6%	8%
15-30% highest NFM woodland potential by catchment area	0%	3%	5%	6%
30-80% highest NFM woodland potential by catchment area	0%	2%	3%	3%
20%lowest NFM woodland potential by catchment area	0%	0%	0%	0%
Temporary storage features				
30% highest NFM storage potential by catchment area	0%	2%	3%	5%
30-80% highest NFM storage potential by catchment area	0%	2%	2%	2%
20%lowest NFM storage potential by catchment area	0%	0%	0%	0%

The opportunity that is realized is controlled by the scale of the ambition for converting BMV land

Associated scale of NFM woodland ambition: BMV land use (% of BMV class land used)									
	Lower			Current			Higher		
Epoch	BMV class 1	BMV class 2	BMV class 3	BMV class 1	BMV class 2	BMV class 3	BMV class 1	BMV class 2	BMV class 3
2020s	0%	0%	5%	0%	0%	5%	0%	0%	5%
2050s	0%	5%	8%	0%	10%	15%	0%	20%	30%
2080s	0%	10%	15%	0%	20%	30%	0%	30%	50%

Variation in impact on reduction in peak flows with return period (as a function of the impact on the 1in50 year flows)

Return period (years)	Return factor on flow reduction
2	2
10	1.5
30	1.25
50	1
100	0.5
1000	0.1

D.5 Urban management

Representation within the FFE

'Urban management' is represented in the FFE through three mechanisms:

- **Take-up of Sustainable Urban Drainage (SUDS) in new developments and retrofitting to existing developments:** From a narrow flood perspective, SUDS reduce surface water run-off and hence the chance of surface water flooding. A review of the application and effectiveness of planning policy for SuDS in England since 2014 (Ministry of Housing, Communities and Local Government, 2018) found that almost 90% of sampled approved planning applications explicitly stated that '*SuDS would feature in the proposed development'* and in Scotland it is anticipated that it would be a 100% *except for single dwellings and those discharging directly to the coast.* It is not known if these conditions were implemented or those implemented will be maintained over the coming century. It is also recognised that permitted developments (patios, driveways, extensions) are excluded from this process and unlikely to incorporate SUDS. Under current adaptation it is assumed that take-up is most across Wales and Scotland (~70%) and England (~50%) for new developments and 5% retrofit across GB. Take-up is less in Northern Ireland (reflecting existing legislation and approaches). Under a higher adaptation future significant increases in take-up are possible through greater integration of planning and investment resources and the incentive for delivering net biodiversity gain.
- **Increase in capacity of conventional drainage network:** Surface water hazard mapping typically includes an assumption regarding the capacity of the drainage network (12mm/hr in England for example), investment (or lack of investment) by water companies can act to increase (or reduce) this capacity. Under a current adaptation future it is assumed there is no change in present day capacity. Under a higher adaptation future it is assumed there is an increase in the investment in urban areas and drainage capacity increases to 15mm/hr (in major and minor urban areas). Conversely, in a lower adaptation future the value reduces to 10mm/year due lack of investment in upgrading networks to account for development and deterioration.
- **Other surface water management measures** (such as gully clearance, preferential surface routing of the flood flows, etc.): These may form part of a surface water management planning in addition to SUDS and reduce the damage. Across all futures it is assumed these actions reduce damages by 5% but are ineffective in reducing damages in the most vulnerable neighbourhoods.

Table 4 Urban management: Adaptation summary

Adaptation measure	2020s			2050s			2080s		
	Lower	*Current*	*Higher*	*Lower*	*Current*	*Higher*	*Lower*	*Current*	*Higher*
#1 Take-up of SUDS in new developments and retrofitting to existing developments									
England									
Existing developments @ significant risk	*0%*	*5%*	*10%*	*0%*	*5%*	*30%*	*0%*	*5%*	*30%*
New developments	*30%*	*50%*	*60%*	*30%*	*50%*	*75%*	*30%*	*50%*	*80%*
Scotland and Wales									
Existing developments @ significant risk	*0%*	*5%*	*10%*	*0%*	*5%*	*30%*	*0%*	*5%*	*30%*
New developments	*30%*	*70%*	*85%*	*30%*	*70%*	*85%*	*30%*	*70%*	*85%*
Northern Ireland									
Existing developments @ significant risk	*0%*	*0%*	*10%*	*0%*	*0%*	*30%*	*0%*	*0%*	*30%*
New developments	*10%*	*15%*	*15%*	*10%*	*15%*	*25%*	*10%*	*15%*	*25%*
#2 Increase in capacity of conventional drainage network (mm/hr)									
Major and minor urban settings	10	12	12	10	12	15	10	12	15
Elsewhere	10	12	12	10	12	12	10	12	12
#3 Other surface water management measures (% reduction in direct economic damage achieved)									
All neighbourhoods	5%	5%	5%	5%	5%	5%	5%	5%	5%
20% most socially vulnerability (by NFVI)	0%	0%	0%	0%	0%	0%	0%	0%	0%

D.6 Spatial planning (Development control)

Representation within the FFE

Spatial planning influences the risk calculation within the FFE through two opposing forces:

- **Development pressure due to population growth:** This drives a change (i.e. an increase, a decrease is not considered here) in the demand for residential properties. The location of new development is then determined by spatial planning settings.
- **Increase in urban footprint:** The change (increase) in urban growth drives an increase in urban run-off (an increase that is moderated by the uptake of SUDS - see earlier adaptation lever).

Table 5 Adaptation measure: Changes in the national average floodplain development

	2020s			2050s			2080s		
	Lower	Current	Higher	Lower	Current	Higher	Lower	Current	Higher
% of all new development in flood prone areas - All neighbourhoods (fluvial and coastal only - excluding Groundwater and surface water)									
England	12%	12%	12%	15%	12%	9%	15%	12%	9%
Wales	12%	12%	12%	15%	12%	9%	15%	12%	9%
Scotland	6%	6%	6%	9%	6%	3%	9%	6%	3%
Northern Ireland	12%	12%	12%	15%	12%	9%	15%	12%	9%
% of all new development in flood prone areas - 20% most socially vulnerable - All neighbourhoods (excluding Groundwater and surface water)									
Increase on above	1.5%	1.5%	1.5%	1.5%	1.5%	0.0%	1.5%	1.5%	0.0%

Note:

The representation of development control in the FFE is significantly improved since CCRA2. The approach now takes account of the updated population projections (including the projected household occupancy – see earlier) and includes an ability to control the proportion of new development being built on the floodplain by Local Authority where available (i.e. England and Scotland).

Relocation is not considered: the impact of active relocation of coastal communities (for example) on risk is not considered here. This would be possible to include and should be carried forward to future assessment.

D.7 Receptor (property – new and existing - and infrastructure) level measures

Representation in the FFE: Residential properties

The FFE reflects two aspects of residential property flood resilience (PFR) (Table 5):

- **% uptake of PFR measures by householders:** differentiating the take-up according to the location of the property (on or off the fluvial / coastal floodplain) and between the most socially vulnerable and less vulnerable neighbourhoods (based on evidence presented, Sayers et al, 2015 and 2016). Changes in uptake may reflect incentives provided by insurers, for example those that may be applied through Flood Re and any transitional arrangements than may come into force after 2039. Although there are several unknowns related to how any incentives may change behavior it is assumed here that they (or similar incentives) would be successful in increasing uptake within the higher (EWS) future.
- **Effectiveness of PFR in reducing damage:** differentiating the reduction of the damage according to the return period of the flood event (given evidence suggesting retrofit measures are likely to be more effective at reducing damages in more frequent events (and shallower depths) and less so in more extreme events (with greater depths). For new developments it is assumed that designs are modified to ensure flood damage is limited (for example by raising floor levels) for events equal to or more frequent than the 1:100-year event.

Table 6 Adaptation measure: PFR: Residential

% uptake of PFR measures (residential)

	2020s			2050s			2080s		
	Lower	Current	Higher	Lower	Current	Higher	Lower	Current	Higher
All households									
Off floodplain fluvial / coastal floodplain									
New properties (% take up)	0%	5%	5%	5%	10%	20%	10%	15%	30%
Existing properties (% take up)	0%	0%	0%	1%	2%	5%	3%	5%	8%
On fluvial / coastal floodplain									
New properties (% take up regardless of the probability of flooding)	50%	80%	95%	50%	80%	95%	50%	80%	95%
Existing properties – % take up in High probability areas	0%	5%	8%	3%	7%	10%	5%	10%	15%
Existing properties – % take up in Low to moderate probability areas	0%	0%	0%	0%	0%	2%	0%	0%	5%
20% most vulnerable neighbourhoods (by NFVI)									
Existing properties – % take up in High probability areas	0%	1%	2%	0%	1%	5%	0%	1%	5%
Existing properties – % take up in Low to moderate probability areas	0%	0%	0%	0%	0%	5%	0%	0%	5%

Reduction damage incurred for those properties protected by PFR measures (regardless of location)

Existing properties

Severity of event	**All neighbourhoods**		
	Reduction in damage (coastal)	**Reduction in damage (fluvial)**	**Reduction in damage (surface water)**
No protection	0%	0%	0%
2	80%	80%	80%
5	80%	80%	80%
10	40%	60%	80%
25	0%	40%	60%
50	0%	0%	40%
100	0%	0%	0%
>200	0%	0%	0%

New properties

Severity of event	**All neighbourhoods**		
	Reduction in damage (coastal)	**Reduction in damage (fluvial)**	**Reduction in damage (surface water)**
No protection	0%	0%	0%
2	100%	100%	80%
5	100%	100%	80%
10	100%	100%	40%
25	80%	80%	40%
50	50%	50%	20%
100	25%	25%	0%
>200	0%	0%	0%

Severity refers to the return period of the flood event. No protection is used to highlight that in the absence of PFR the damage to the property is not moderated by PFR.

Representation in the FFE: Non-residential properties and infrastructure

Representation in the FFE follows the same approach as for residential properties (above) but with variations in uptake and damage reductions are summarised in Table 7.

Table 7 Adaptation measure: PFR: Non-Residential

% uptake of PFR measures (non-residential)

	2020s			2050s			2080s		
	Lower	Current	Higher	Lower	Current	Higher	Lower	Current	Higher
Off floodplain fluvial / coastal floodplain									
% uptake for non-residential properties and Category B infrastructure (Irrespective of flood prob.)	0%	2%	2%	2%	3%	7%	3%	7%	13%
% uptake for Category A infrastructure (irrespective of flood prob.)	0%	5%	5%	5%	10%	20%	10%	20%	40%
On fluvial / coastal floodplain									
% uptake for non-residenital and Category B infrastructure in High probability areas	15%	25%	40%	30%	50%	60%	30%	50%	60%
% uptake for non-residential properties and Category B infrastructure in Moderate and Low probability areas	4%	6%	10%	8%	13%	15%	8%	13%	15%
% uptake for Category A infrastructure providers (irrespective of flood prob.)	15%	25%	40%	30%	50%	60%	30%	50%	60%

Note: Category A - including Water infrastructure and Energy infrastructure. All other non-residential and infrastructure assets are considered Category B.

Reduction damage incurred for those properties protected by PFR measures (regardless of location)

Severity of event (years)	All neighbourhoods		
	Reduction in damage (coastal)	**Reduction in damage (fluvial)**	**Reduction in damage (surface water)**
No protection	0%	0%	0%
2	100%	100%	80%
5	100%	100%	80%
10	100%	100%	40%
25	80%	80%	40%
50	50%	50%	20%
100	25%	25%	0%
>200	0%	0%	0%

Severity refers to the return period of the flood event. No protection is used to highlight that in the absence of PFR the damage to the property is not moderated by PFR.

D.8 Forecasting and warning

Providing actionable forecasts and warnings to communities is an essential component of flood risk management (e.g. Parker *et al.,* 2009; Parker *et al.,* 2011, Sayers et al, 2014). Communities and individuals that are aware of risk and who receive trusted and meaningful flood warnings are better able to prepare for, and respond to, a flood (including taking damage-reducing actions and developing strategies to minimise the impact of the flood on their families and property). The ability to respond is therefore fundamentally affected by the timeliness of reliable warnings, the clarity of messages to act, and the ability of those involved to take action to help themselves or others.

Good forecasting and warning is therefore necessary but it is not sufficient, and ultimately, it is the ability of people to respond to this information which makes the difference (Thrush *et al*., 2005). Local authorities and agencies often have records of vulnerable people (such as older people with physical disabilities in receipt of care services) to help target assistance when a flood is imminent. Community networks (including informal and formal networks and "action groups") also play a significant role in improving the response and recovery of the community (Walker *et al.*, 2010; Geaves and Penning-Rowsell, 2014). But the impact of such networks on individuals experience of flooding is less clear, with Green (1995) finding that the extent and type of social support received by victims of flooding seemed to have no effect on the victims' level of stress or amount of disruption from a flood event.

In England, the Environment Agency allocates spending on flood warning based on a Flood Warning Investment Strategy (Ball *et al.,* 2012). They conduct a 'levels of service assessment' to allocate funding priorities for flood warning according to location, thereby establishing target standards of quality for the service in each flood warning area. This assessment reflects SOP and impact, without any specific consideration being given to vulnerability (Andryszewski *et al.,* 2005). In recent years there has been a significant expansion of 'Floodline Warnings Direct' (FWD), a centrally hosted warning and dissemination system that sends messages to the telephones of people in flood warning areas. SEPA provides a similar service in Scotland (although in Scotland current sign-up rates are significantly lower than those in England, as advised by SEPA for Sayers et al, 2017 study; perhaps reflecting the 'opt out' policy approach in England and 'opt in' approach Scotland). In Wales, Natural Resources Wales (NRW) have been responsible for flood warnings since April 2013 (Wales Audit Office, 2016). In Northern Ireland, the Rivers Agency currently has no warning service but they have published maps of areas at high flood risk (Rivers Agency, undated) - as have other nations.

In determining the ability of forecasting and warning to reduce damage the central adaptation scenario is assumed to reflect current evidence, notionally (based on CCRA2, Sayers et al., 2015 and studies for the JRF, Sayers et al, 2016):

- **The take-up of warning services is greatest in coastal areas:** This reflects the heightened perception of risk (Parker, 1991 and Parker et al., 2007) and the maturity of the flood warning system since it was implemented after the 1953 event. Numerous events have been tracked down the North Sea during this time, and warnings to the communities affected have become better publicized and more targeted because of this experience.
- **Surface water and flash flood forecasting**: Effective forecasting and warning of surface water and flash floods (capable of reducing direct damages) remains limited but efforts to improve these capabilities are under development.
- **The effectiveness, in terms of reduction in damage, increases with lead time and experience:** Longer lead time, and hence greater opportunity to act, is often associated with more extreme events (Parker, 1991). Although this is not always the case (for example the ability of warnings to reduce damage during flash flood events, as experienced in Boscastle in 2004, is typically very low despite the rarity of the event. In many fluvial and coastal flood events however a higher return period is often associated with longer lead times and this increases the opportunity for

people to take risk reducing actions, such as in Tewkesbury in 2007. Prior experience of flooding is also often associated with higher levels of action. This is typically associated with areas that see more frequent flooding. These competing tendencies make it difficult to distinguish damage reduction by event.

- **The absence of community networks:** In the most vulnerable neighbourhoods (as defined by the NFVI) informal community networks can be much reduced (RSPB, 2014, Sayers et al, 2017).
- **Ability to respond:** Not everyone is able to respond as easily to warnings as others. For example, a limited physical mobility may impact an individual's ability to deploy flood protection measures at home, such as flood gates, in the case of rapid onset events like surface water flooding is likely to be (Defra, 2007b).

Note:

CCRA3 extends the representation used in the CCRA2 to include differentiation by social vulnerability and revisits the assumption effectiveness based on evidence presented in detail in Sayers et al, 2016. As in the CCRA2, there is no consideration of loss of life here. Although it is recognised that flood forecasting and warning is primarily targeted towards saving lives, the impact on people (and the ability for people to successfully evacuate etc.) is not included here.

Rapid response catchments: The ability to provide forecasts to reduce impacts in fluvial flooding in 'flashy' catchments is not differentiated here from other fluvial floods; a shortcoming that may overstate the capability of forecasting and warning in Scotland and Wales in particular.

Role of prior flood experience: This is often associated with higher levels of action and people in areas which flood reasonably frequently are more likely to have prior experience of a flood. This matches anecdotal evidence from the 2015/16 floods where some people were very surprised to discover they lived in an area of flood risk. This awareness is countered but the shorter lead time that is typically associated with more frequent events. This combination of issues should be considered in more detail for future assessments.

Representation within the FFE

The ability of forecasting and warning to reduce economic damage rely on the success of a chain of activities (for example see Environment Agency, 2015). These aspects are reflected within the FFE through following considerations and listed below and summarised Table 8: (a) **% properties that successfully receive and act upon a warning, that in turn is defined as an aggregate four user controls**: this is determined based on four aspects (i) % coverage of the flood warning service (residential); (ii) % take up of residential properties; (iii) % of those that receive a warning when signed up; (iv) % of those that take appropriate action and the actions taken are effective; (b) **% reduction in direct residential property damages:** % reduction in the estimated damages

Table 8 Adaptation measure: Flood Forecasting and warning

All households

		2020s			2050s			2080s		
	Present day	Lower	Current	Higher	Lower	Current	Higher	Lower	Current	Higher
% properties that successfully receive and act upon a warning										
Coastal areas	43%	51%	58%	66%	68%	77%	87%	77%	77%	87%
Fluvial areas	26%	32%	37%	43%	45%	53%	60%	53%	53%	60%
Surface water areas	6%	8%	9%	11%	11%	13%	15%	13%	13%	15%
% reduction in DIRECT damages given appropriate action taken										
All sources and across all return periods	10%	10%	10%	10%	12%	12%	12%	14%	14%	14%

20% most socially vulnerable neighbourhoods (by NFVI)

		2020s			2050s			2080s		
	Present day	Lower	Current	Higher	Lower	Current	Higher	Lower	Current	Higher
% properties that successfully receive and act upon a warning										
Coastal areas	6%	12%	17%	23%	28%	38%	49%	38%	38%	49%
Fluvial areas	0%	2%	4%	6%	9%	14%	20%	14%	14%	20%
Surface water areas	0%	1%	1%	1%	2%	4%	5%	4%	4%	5%
% reduction in DIRECT damages given appropriate action taken										
All sources and across all return periods	10%	10%	10%	10%	12%	12%	12%	14%	14%	14%

D.9 Insurance

Representation of adaptation in the FFE

Within the FFE, flood insurance acts to reduce the number households suffering an uninsured loss. Where flood insurance is in place it is assumed that households can cover the full economic loss caused by the flood (excesses or other constraints on what can and cannot be claimed, and the difference between economic and financial losses are not considered). The central issue considered is therefore penetration. To determine these values consideration has been given to:

- ***Penetration of insurance:*** evidence from the summer 2007 floods in England suggests that 76 per cent of household losses (building and contents) are covered by insurance (see Table 2.1, Chatterton *et al.,* 2010). We assume here that this is indicative of the penetration in all other neighbourhoods other than those that are the most vulnerable. In the most vulnerable neighbourhoods we assume there is a lower penetration of insurance (see table below).
- ***Tenure of the property:*** Evidence suggests that tenants are more likely than homeowners to have little or no flood insurance, and are often very significantly underinsured (ABI, 2010; ONS, 2015). Approximately 40 per cent of those in some form of rented accommodation take-up flood insurance (The Poverty Site, undated);
- ***Low income****:* Only one in three adults earning between £150-250 per week has home contents insurance compared with around 70 per cent of those on more than £600 per week (2015 Family Expenditure Survey, now called the Living Costs and Food Survey (ONS, 2015)). Around 55 per cent of households within the bottom 10 per cent by income have no flood insurance (ABI, 2010);
- ***Direct experience of flooding:*** It is unclear if direct experience of flooding affects the propensity to insure. Kates (1962) shows that direct experience triggers response, but that is not quite as direct as to say it triggers insurance. To reflect this relationship, it is assumed here that in areas prone to more frequent flooding the awareness of the risk faced is higher (and those living there are, on average, more likely to have been flooded previously. This translates to higher take-up rates in areas prone to more frequent flooding (although marginal).
- ***Surface water flood areas*****:** Insurance does not consider the source of flooding at all. It is all included, but awareness of surface water risk is much less than fluvial or coastal risks.
- ***The move towards actuarial pricing after Flood Re*****:** The evidence presented above predates the introduction of Floods Re. Flood Re may have a positive impact on penetration but as yet this is unknown. Within the current objectives adaptation portfolio no adjustment is made to take account of Flood Re and no adjustment is made to reflect its proposed cessation in 2039. In the lower adaptation future (no additional action) it is assumed that no mechanism is put in place to replace Floor Re and insurance pentation significantly reduces.

In combination, these influences are translated into the specific changes within the FFE as below.

Table 9 Adaptation measure: Insurance penetration

% penetration of insurance (residential properties)

Example for those at significant chance of flooding (1in75 years): Coastal	Present day	2020s			2050s			2080s		
		Lower	Current	Higher	Lower	Current	Higher	Lower	Current	Higher
Homeowners - contents										
All households	76%	76%	76%	76%	53%	76%	76%	53%	76%	76%
Low household income (20%ile)										
No history of flooding	38%	38%	38%	38%	27%	38%	38%	27%	38%	38%
Direct experience of flooding in the area	45%	45%	45%	45%	32%	45%	45%	25%	35%	35%
Tenants (Social and private) - contents										
All households	76%	76%	76%	76%	38%	76%	76%	38%	76%	76%
Low household income (20%ile)										
No history of flooding	20%	20%	20%	20%	10%	20%	20%	10%	20%	20%
Direct experience of flooding in the area	32%	32%	32%	32%	16%	32%	32%	16%	32%	32%

D.10 Governance and organisational arrangements

Representation of adaptation in the FFE

No effort is made here to quantity the influence of governance and institutional capacity on flood risk within the FFE (although research is emerging to explore this more quantified relationship within the EC Funded Cloud-2-Coast adaptation project[1]). Governance arrangements that deliver the above are a pre-requisite to achieving the current or higher adaptation outcomes in practice.

D.11 References

See Main Report

[1] https://northsearegion.eu/c5a/about/