

APPENDIX C. EXOGENOUS CHANGE: CLIMATE AND SOCIO-ECONOMIC CHANGE

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C.1 Climate change

Two climate projections are considered, a 2°C and 4°C rise in Global Mean Temperature (GMT) by 2080s (from the 1961-90 baseline as used in UKCP09). These are the same as those used for the UK Climate Change Risk Assessment (CCRA, as set out in Sayers *et al.*, (2015)). For each projection, consideration is given to changes in mean sea level, peak fluvial flows and short duration rainfall, all of which act to change the probability of flooding.

Tables C-1 to C-3 present a summary of the changes in both native units (i.e. mm/year for sea level rise) and the associated change in the return period of extreme events. More detail on the data sources used and supporting analysis is given in Sayers *et al.* (2015a).

Note: No consideration is given here to the growth of the floodplain that may result from climate change. Only the probability of flooding within the present day, undefended, 1:1000 year return period floodplain is considered. Notwithstanding the potential expansion of the floodplain under more extreme assumptions of sea level rise (as explored in Sayers *et al.*, 2015 and subsequent discussion in Edwards, 2017) this static, but broad, definition of the floodplain is considered a reasonable assumption in the context of this study.

Table C-1 Climate change: Coastal flooding (from Sayers *et al.*, 2015b)

a) Relative Sea Level Rise projections (m) from a 2014 baseline

Region	2°C Projection			4°C Projection		
	2020s	2050s	2080s	2020s	2050s	2080s
England and Wales (based on Deakin <i>et al.</i> , 2001, <i>apud</i> Sayers <i>et al.</i> , 2015b)						
Lincolnshire (East coast)	0.03	0.13	0.26	0.14	0.37	0.64
Dungeness (South-east coast)	0.03	0.14	0.26	0.14	0.37	0.64
Lyme Bay (South-west coast)	0.03	0.15	0.28	0.15	0.38	0.66
Swansea (Mid-west coast)	0.03	0.13	0.25	0.14	0.36	0.63
Flyde (North-west coast)	0.02	0.11	0.21	0.14	0.34	0.59
Scotland (locations based on CREW, 2012, <i>apud</i> Sayers <i>et al.</i> , 2015b)						
Edinburgh	0.02	0.08	0.17	0.13	0.32	0.55
Aberdeen	0.02	0.09	0.18	0.13	0.32	0.56
Wick	0.02	0.11	0.21	0.14	0.34	0.59
Lerwick	0.04	0.16	0.30	0.15	0.39	0.67
Ullapool	0.02	0.09	0.18	0.13	0.32	0.56
Stornoway	0.02	0.11	0.22	0.14	0.34	0.59
Tobermory	0.02	0.08	0.16	0.13	0.31	0.54
Millport	0.02	0.08	0.16	0.13	0.31	0.54
Northern Ireland						
NI - All	0.02	0.09	0.17	0.13	0.32	0.55

b) Example changes in the Standard of Protection by 2080s: 2°C climate change projection

Location	England and Wales					Scotland								Northern Ireland
	East Coast	South-east	South-west	Mid-west	North-west	Edinburgh	Aberdeen	Wick	Lerwick	Ullapool	Stornoway	Tobermory	Millport	All
Analogous region in England and Wales						East Coast	East Coast	East Coast	South West	South West	South West	South West	North West	North West
Present day SoP (return period, years)	Future SoP (return period, years)													
Coastal defence type: Vertical Wall														
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
5	3	4	3	3	3	4	4	3	3	5	4	5	4	4
10	3	4	3	3	3	4	4	3	3	5	4	5	4	4
20	4	4	8	3	5	6	6	5	4	7	6	8	6	6
50	13	4	23	3	16	20	19	16	15	24	20	27	21	20
100	20	8	61	5	32	30	29	24	22	36	30	40	32	39
200	53	20	153	17	48	80	77	63	58	95	80	108	86	59
Coastal defence type: Embankment														
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
5	3	4	3	3	3	4	4	3	3	5	4	5	4	4
10	4	4	3	3	3	6	6	5	4	7	6	8	6	4
20	7	4	5	5	5	10	10	8	7	12	10	13	11	6
50	13	4	23	9	16	20	19	16	15	24	20	27	21	20
100	33	6	61	17	32	50	48	40	36	59	50	67	54	39
200	93	10	123	26	96	141	134	111	102	166	140	189	150	117
Coastal defence type: Shingle beach														
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
5	3	4	3	3	3	4	4	3	3	5	4	5	4	4
10	4	4	3	3	3	6	6	5	4	7	6	8	6	4
20	7	4	5	5	5	10	10	8	7	12	10	13	11	6
50	13	4	23	9	16	20	19	16	15	24	20	27	21	20
100	40	6	61	26	32	60	57	48	44	71	60	81	64	39
200	106	10	123	34	80	161	153	127	116	189	160	200	172	98

Example:

By the 2080s, the Standard of Protection (SOP) afforded by a vertical wall in the north-west of England with a current SoP of 1:100 would reduce to 1:32 years due to sea level rise, given a 2°C climate change projection (assuming no other change).

Table C-2 Climate change: Fluvial flooding (from Sayers *et al.*, 2015b)

a) Percentage change (+ increase/- decrease) in peak flows from 1990 baseline

Country	Region	2°C Projection			4°C Projection		
		2020s	2050s	2080s	2020s	2050s	2080s
England and Wales	Northumbria	5	8	13	16	21	31
	Humber	3	8	13	16	21	31
	Anglian	-3	3	10	18	24	42
	Thames	-3	3	10	18	24	42
	South East	-3	8	15	18	33	56
	South West	5	10	18	21	28	47
	Severn	0	8	13	16	28	42
	Dee	5	8	13	14	21	29
	North West	10	15	20	19	26	43
	Solway	10	18	18	19	26	40
	Tweed	8	13	23	19	26	32
	Western Wales	3	8	13	15	24	36
Scotland	Orkney and Shetland	11	19	27	16	22	33
	North Highland	7	13	18	14	19	29
	West Highland	12	21	30	22	30	45
	North East Scotland	5	9	13	8	11	17
	Argyll	12	21	30	22	30	45
	Tay	6	11	16	13	17	26
	Clyde	8	14	20	17	23	34
	Forth	7	12	17	14	19	28
	Solway	7	13	18	16	21	32
Tweed	6	10	14	11	15	23	
Northern Ireland		13	13	21	13	21	39

b) Example relationship between percentage changes in peak flow (from (a) above) and return period

Region 1	Northumbria										
	Current Return Period (years)										
% change in peak flow	2	2.3	5	10	25	50	100	500	1000	5000	10000
	Revised Return Period (years) given a change in peak flow										
-40	196	169	235	473	1330	2967	6648	43094	95943	607852	1339346
-20	6.8	7.9	19	43	123	268	582	3441	7345	42206	89230
-10	3.2	3.7	8.9	19	51	107	224	1229	2544	13687	28180
-5	2.4	2.8	6.5	13	35	72	147	772	1571	8157	16557
0	2.0	2.3	5.0	10	25	50	100	500	1000	5000	10000
+5	1.7	1.9	4.0	7.7	18	35	69	333	654	3147	6199
+10	1.5	1.7	3.3	6.1	13	26	50	227	439	2031	3940
+15	1.4	1.5	2.8	4.9	10	19	37	159	302	1343	2564
+20	1.3	1.4	2.4	4.1	8.6	15	28	114	212	908	1706
+25	1.2	1.3	2.1	3.5	7.0	12	21	84	153	627	1159
+40	1.1	1.1	1.6	2.4	4.2	6	11	37	64	232	408

Example:

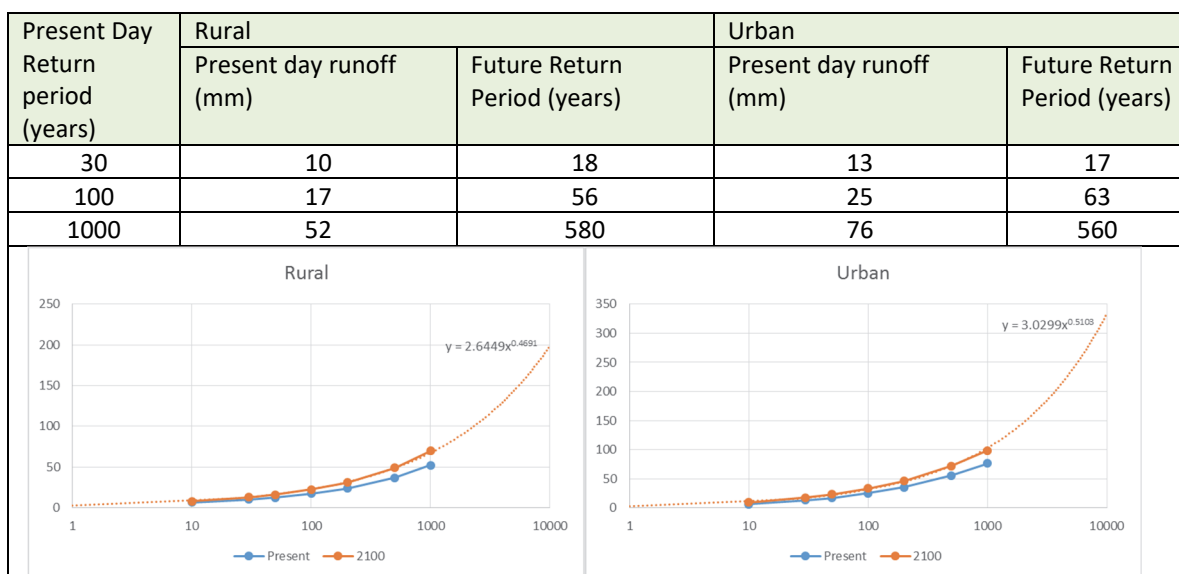
A 10% increase in peak flow (+10%) reduces the return period of flow from 1:100 to 1:50 years.

Table C-3 Climate change: Surface water flooding (from Sayers *et al.*, 2015b)

a) Percentage changes in intense rainfall of less than or equal to 6 hours duration

Global Mean Temperature change (from 1990 baseline)	2020s	2050s	2080s
2°C Projection	0	+10%	+20%
4°C Projection	+10%	+20%	+50%

b) Example of present day runoff, and the return period of that runoff value in 2100 climate, assuming 20% uplift in intense rainfall of less than or equal to 6 hours



*The example results are based on the runoff-frequency curves shown in the bottom row for rural and urban areas.

C.2 Population growth

The Office for National Statistics (ONS) produce population projections for England, Wales, Scotland and Northern Ireland to 2100, with sub-national population projections to 2037. The Adaptation Sub-Committee (ASC) extrapolated this data to provide population projections to 2100 for Low, Principal and High population growth variants at a local authority level (Sayers *et al.*, 2015c).

The Low and High variants used here generally indicate a growth in population (particularly London and the south-east of England). The only exceptions to this are in Northern Ireland (where, under the low growth variant, population decreases slightly by 2080s) and in Wales (where, under the low growth variant, population decreases slightly between the 2050s and 2080s).

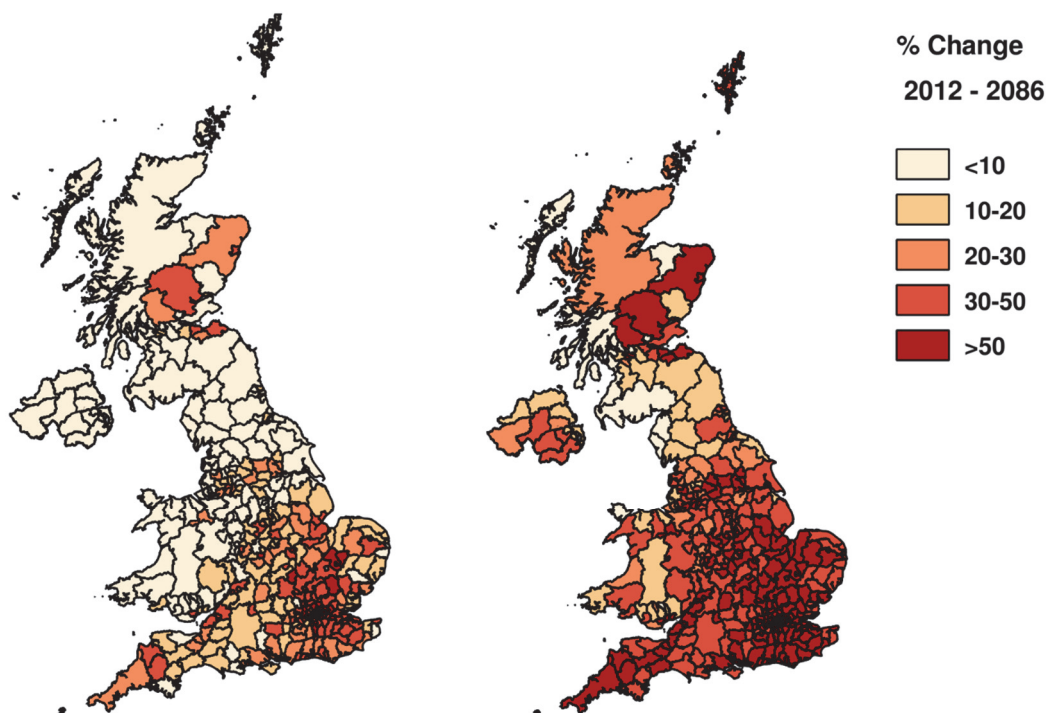
Locally applicable property occupancy rates (derived at neighbourhood scale based on property and census data) are used to translate the population projections to the construction of new residential properties on the floodplain (after taking appropriate account of spatial planning).

The population growth projections are summarised in Table C-4 and Figure C-1.

Note: It is assumed that occupancy rates remain constant into the future (despite occupancy rates being predicted to fall by 6% by 2037). This is because of difficulties in meaningfully differentiating changes across neighbourhoods, but could be explored further in future analysis. Non-residential properties are assumed to remain unchanged.

Table C-4 Future population growth: A summary (Sayers et al., 2015b)

Region	Current population (at 2012)	Future Population (total no. of people) and growth (as a % change from 2012)					
		Low			High		
		2020s	2050s	2080s	2020s	2050s	2080s
UK	63.7m	68.4m +7%	74.2m +17%	76.5m +20%	70.1m +10%	83.0m +31%	97.2m +53%
England	53.5m	57.7m +8%	63.4m +18%	65.9m +23%	59.2m +11%	70.9m +33%	83.7m +56%
Wales	3.08m	3.21m +4%	3.25m +5%	3.18m +3%	3.29m +7%	3.63m +18%	4.07m +32%
Scotland	5.31m	5.53m +4%	5.67m +7%	5.63m +7%	5.67m +7%	6.35m +20%	7.17m +36%
Northern Ireland	1.82m	1.92m +6%	1.93m +6%	1.77m -3%	1.97m +8%	2.16m +19%	2.30m +27%



Left: Low growth variant. Right: High growth variant

Figure C-1 Projected population increases by local authority area (Sayers et al., 2015b)

C.3 Demographic change (Age profile)

Between 2014 and 2025 the numbers aged over 75 are expected to increase by 37% (2.2 million). This compares to an expected growth of 8% in population as whole (ONS 2014 principal projection – Figure C-2). Growing numbers of elderly people, and the increasing number of under 5 year olds projected to occur from around the 2040s, could have a significant influence on overall vulnerability. However, given that the ONS 2014 principal projections for the Under 5s and Over 75s (Table C-5) provide no information on change in the spatial distribution of age this has no impact on the NFVI or SFRI z score ranking. The age projection does however impact the number of elderly and very young people that may be at risk.

Table C-5 Changing demographics: Percentage change in population under 5 and over 75 years old

Age Category	% increase by year (ONS, 2014 Principal Projection)		
	2025	2055	2085
Under 5	1.3%	8.2%	15%
Over 75	37%	128%	185%
General population	8%	22%	34%

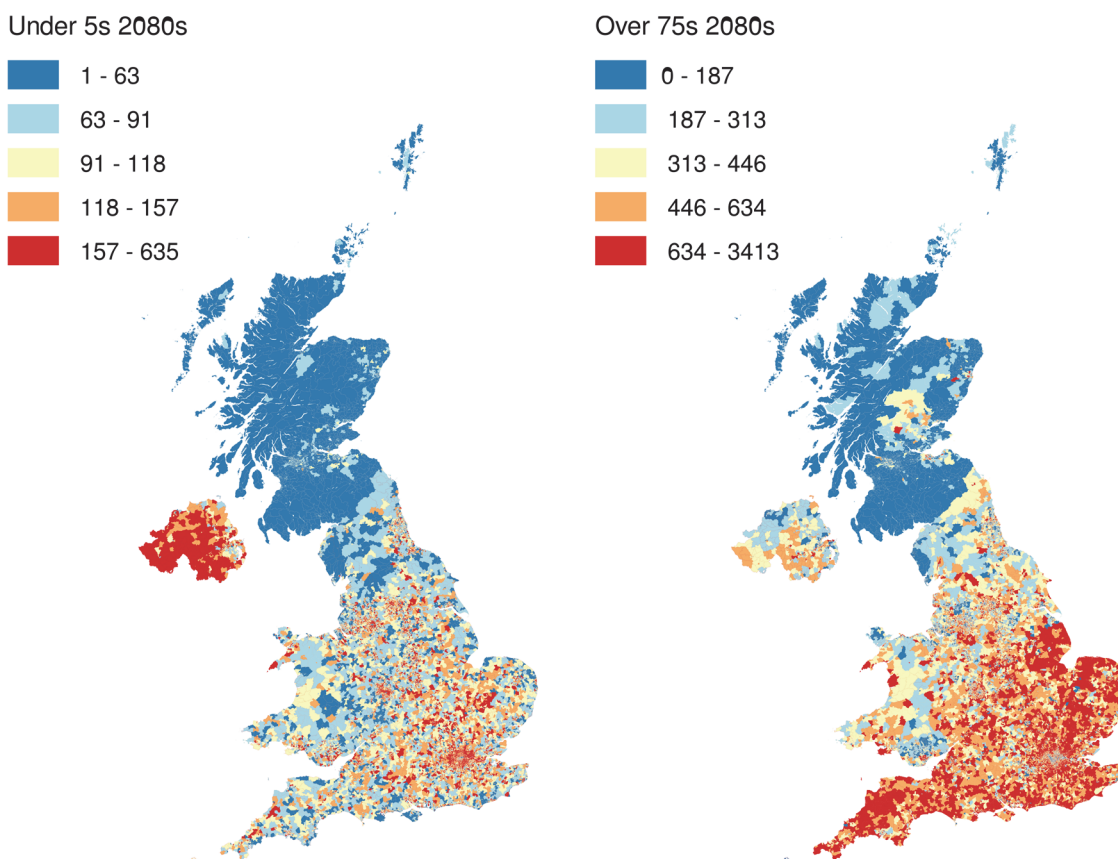


Figure C-2 Population by growth by age category, 2085, high growth variant

C.4 References

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Deakin, R., Burgess, K., Samuels, P., Sayers, P and Chatterton, J. (2001). **A national economic appraisal of the impacts of flooding and coastal erosion considering the impacts of climate change**. MAFF Flood and Coastal Defence Conference (p. 9). MAFF.

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