5 OVERVIEW OF MODEL RESULTS FOR THE BARNSTAPLE AREA

This section provides an overview of fluvial and tidal flood risk across the Barnstaple area in order to put into context the selection of the potential development sites and provide information for use in future development planning.

For overviews of model results from the Barnstaple 2D Modelling and Mapping study including extent, depth, velocity, hazard, areas benefiting from defences and the Flood Zone 3a/3b split, see accompanying A1 maps listed in the table of contents (Appendix D).

In general the watercourses in and around Barnstaple flow through steep sided valleys therefore the flooding associated with them (under current defended conditions) is small in extent where it is constrained by topography. However, this means that where flooding does occur, even if over a very small area the depths are likely to be significant. This is supported by the hazard maps, which although showing a variety of hazards, demonstrate that all of the modelled watercourses have areas of extreme hazard associated with the 1 in 100yr fluvial and 1 in 200yr tidal events. The tidal flood risk is generally less than fluvial, although still significant.

Based on the model results, the overviews highlight two key areas of flooding. Both the land surrounding Bradiford Water and Pilton Park were observed to flood with low onset return periods and significant depths and hazard for all fluvial and tidal flood events. However, both Pilton Park and the lower reaches of Bradiford Water have been designed to act as flood storage areas (FSAs) therefore they would be expected to flood. The effects of climate change were also evident in this area, during a 1 in 200 year tidal flood event in both 2070 and 2115 the areas of Pilton, Bradiford and many other areas within Barnstaple such as Pottington, are projected to experience severe flooding (see Appendix D).

5.1 Flood probability (with defences)

FLUVIAL

As shown on the A1 maps provided in Appendix D, the onset of fluvial flooding across most of the Barnstaple area occurs at the QMED event (see glossary), especially at the following locations:

- Where Fremington Stream becomes Fremington Pill,
- Along the lower reaches (approximately 1.5km) of Bradiford Water,
- At the FSA at Pilton Park on the River Yeo and at Green Meadow Drive
- Upstream of Rock Park at Portmarsh Lane / Victoria Road in relation to the Coney Gut.
- Quite extensively along Rumsam Stream and the Tributary to the Taw at Pill Farm and,
- To a lesser extent at Shoreleigh Bridge and along Venn Stream at Bishop's Tawton in the area of School Lane, Sanders Lane and Easter Street.

Fluvial flood extents were not observed to increase significantly for the 1 in 5year event except at:

- Scottsmoor on Bradiford Water,
- Raleigh Meadows on the Yeo,

- Along Venn Stream (by approximately 20-40m laterally) and,
- Along the River Taw adjacent to Bishop's Tawton where extents were recorded to expand in the order of 200m onto the rural land either side of the channel.

Little difference was noted for the 1 in 10year fluvial event, however by the 1 in 20 year event, significant flooding was observed to occur at the confluence of Bradiford Water with the Taw in the vicinity of Ashford. Increases in extent were also noted at:

- Scottsmoor on Bradiford Water,
- Along the Muddle Brook at Sheiling Road and
- At the Whiddon Valley industrial estate on the Coney Gut.

At the 1 in 50year fluvial event a significant increase in flooding is noted at Ashford to the west of Bradiford Water. Minor increases in extent were observed along:

- Fremington Stream as it flows through Fremington,
- The Coney Gut at the Whiddon Valley Industrial estate and Rock Park,
- The River Yeo at Raleigh Meadows and,
- The tributary to the Taw / River Taw between Lake and Sticklepath.

No major increases in fluvial flood extent were noted for either the 1 in 75year event or the 1 in 100year event.

For the 1 in 1000year event, model results indicate further inundation at Scottsmoor and considerable flooding along the Coney Gut from the Community Centre at Newport (a lateral increase of 15-60m from the 100yr extent) to its confluence with the Taw. All of Rock Park and the adjacent sports ground is expected to become flooded up to 'The Strand' and down to Rumsam Stream.

The fluvial flood extents for the 1 in 100year event plus climate change (accounting for an increase in flows of 20%) are similar to those of the 1 in 1000year event although greater in the vicinity of Ashford, Pilton Park and Sticklepath.

TIDAL

As shown on the A1 maps provided in Appendix D, in general under current conditions the tidal flood extents are smaller than the fluvial flood extents. The 1 in 10year was the lowest modelled tidal event and similar to the fluvial QMED, there are several locations where, based on the Barnstaple 2D Modelling and Mapping results, this represents the onset of flooding:

- The Taw at Chivenor (as mentioned in section 4.15.4 it is understood that detailed modelling of the Chivenor/Wrafton area has been carried out incorporating recently constructed flood defences. This modelling should be consulted prior to development planning)
- The lower reaches (approximately 1.5km) of Bradiford Water,
- Pilton Park on the River Yeo and at Green Meadow Drive
- Upstream of Rock Park at Portmarsh Lane / Victoria Road in relation to the Coney Gut.
- Pillmere, to the south of Rock Park
- Rumsam Stream
- Tributary to the River Taw at Lake
- Shoreleigh Bridge
- Venn Stream

This may mean that there are areas where the standard of defence is lower than previously thought.

Further to this, model results show significant increases in tidal flood extent with increasing return period up to and including the 1 in 200year event at Pilton Park, Anchorwood / Sticklepath (where defences along the River Taw appear to overtop at the 1 in 20year event), Rock Park and along the Taw adjacent to Bishops Tawton.

Contrary to the fluvial flood extents, the effects of climate change are projected to have a substantial impact on tidal flooding in the Barnstaple area. By the year 2070, flooding from a 1 in 200 year event in the areas specified above is projected to increase, with additional tidal flooding behind the Tarka Trail at Bickington, to the west of Fremington and in the locality of the superstores adjacent to the Coney Gut in Newport.

By 2115, large increases in tidal flood extent are anticipated at Chivenor (based on Barnstaple 2D Modelling and Mapping study), west of Fremington, Ashford and Bradiford Water. Most of Pottington Business Park, Pilton, and the modelled reach of the Yeo incorporating Yeo Vale Road, St Georges Road and Lower Raleigh Road are projected to become inundated during a 1 in 200 year event. The Civic Centre, North Walk, Castle Street and the area between The Strand and Queens Street are also recorded to experience flooding. Lateral increases in extent along the Coney Gut of over 100m are observed from the community centre at Newport to its confluence with the Taw. Smaller increases are noted at Rumsam, Venn Stream and Lake, and at the industrial estate at Sticklepath with lateral increases of up to 30m along the Muddle Brook and Fremington Stream.

5.2 Flood Zone 3a / 3b

As part of this Level 2 SFRA, Royal Haskoning have undertaken an exercise to define the function floodplain. The division of Flood Zones 3a and 3b has been based on the model results. A1 maps in Appendix D have been produced showing both tidal and fluvial Flood Zones 3a / 3b. The fluvial split was derived from the 1 in 100 year undefended and 1 in 20 year defended extents. Normally undefended model results would be used but due to data limitations defended results have been used instead. This is sufficient for the Level 2 SFRA because most areas do not have defences. The tidal split was based on the 1 in 20 year defended extent and EA tidal Flood Zone 3 (as this represents the 1 in 200 year undefended extent).

The fluvial and tidal Flood Zones 3a are similar in extent although in general the tidal extent is slightly larger than the fluvial, especially at Pilton, Pottington and Sticklepath.

Fluvial and tidal Flood Zones 3b are also similar, extending over the floodplain at:

- Bradiford Water,
- Pilton Park and Underwood Meadows in relation to the River Yeo,
- Portmarsh Lane and Rock Park along the Coney Gut,
- The land adjacent to Venn Stream,
- Land between Lake and Bishops Tawton along the Taw (at this location and at Ashford the fluvial Flood Zone 3b is greater than tidal) and
- The lower reaches of Fremington Stream.

The implications of this Flood Zone split is that only the following uses as defined by PPS25 in the Flood Risk Vulnerability Classification are suitable for FZ3b:

- Essential transport infrastructure,
- Strategic utility infrastructure,
- Flood control infrastructure,
- Water transmission infrastructure and pumping stations,
- Sewage transmission infrastructure and pumping stations,
- Sand and gravel workings,
- Docks, marinas and wharves,
- Navigation facilities,
- MOD defence installations,
- Ship building, repairing and dismantling, dockside fish processing and compatible activities requiring a waterside location,
- Water-based recreation (excluding sleeping accommodation),
- Lifeguard and coastguard stations,
- Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities,

The impact of climate change is not expected to greatly affect the extent of the fluvial Flood Zones 3a / 3b. Flood Zone 3b in particular is not projected to increase beyond the current Flood Zone 3b extent.

For the tidal Flood Zones 3a / 3b, the effects of climate change by 2115 result in significantly increased extents, particularly for Flood Zone 3b, with the implications that the suitability of land for residential development across the Barnstaple area is limited in the vicinity of Sticklepath, the Great Western Industrial Estate and superstores at Newport, Lake, Pilton, Pottington, Chivenor, Rock Park and along the River Taw between Lake and Bishops Tawton.

5.3 Flood Depth

Fluvial flood depths for the 1 in 100 year (defended) event vary considerably across the modelled area. From its confluence with the Taw to Chaddiford Lane, fluvial flood depths along Bradiford Water are generally in excess of 1m, falling to less than 0.5m upstream. Along the River Yeo, depths are mostly less than 0.5m except at Pilton Park where they increase significantly to between 1.5 and 1.75 m.

Areas of considerable fluvial flood depth on the Coney Gut include land at Portmarsh Lane (up to 1.25m), Rock Park (>0.5m) and at the confluence of the Whiddon Valley Stream with the Coney Gut where maximum depths of over 2.5m are recorded.

Along Muddle Brook and Fremington Stream, fluvial depths are quite small, on average <0.25m until Fremington Stream reaches Fremington Manor grounds where depths increase rapidly to over 3m as the watercourse becomes Fremington Pill.

Between the Taw and Lake (along the tributary to the Taw) and at the ground to the south of Rock Park Sports Ground model results show fluvial flood depths of over 2m increasing to more than 3m on the land either side of the Taw at Bishops Tawton. Depths are also significant along Venn Stream with maximum depths of over 2m in the vicinity of School Lane.

Due to the effects of climate change, fluvial flood depths are projected to increase in the locations discussed above by an average of 0.5m.

For the 1 in 200 year (defended) tidal event, flood depths are deep in the same locations as for the fluvial 100 year event although generally lower by approximately 0.5m, except at Pilton Park which has a tidal flood depth of 0.5m greater than the fluvial depth.

Average tidal flood depths are generally projected to increase significantly across most of the Barnstaple area as a result of climate change. Table 5.3.1 details where major changes in tidal flood depths are expected to occur by the years 2070 and 2115. Note that flood depth is predicted to decrease by 2070 at Bradiford Water, this is due to the significant increase in flood extent.

Table 5.3.1 - Changes in tidal flood depth due to the effects of climate change

Location	Change in 1 in 200 year Depth (m)	
	By 2070 (change from current)	By 2115 (change from 2070)
Bradiford Water	-0.25	+3
Pottington Business Park	0	+1
Pilton park	+0.5	+0.7
Ground at Portmarsh Lane	+0.5	+1.5
Rock Park adjacent to Taw	+1.5	+1.5
Rock Park Sports Ground	0	+2
Along River Taw by Bishops Tawton	+2.5	+0.7
Between River Taw and A361 at Lake	+1	+1
Retail park at Anchorwood	+0.5 – 2.5	+1
Fremington Stream by Fremington Manor Grounds	+0.8	+0.6

5.4 Flood Velocity

Across the Barnstaple area the 1 in 100 year fluvial flood velocities are mostly low (less than 0.1m^3/s) except at the upstream extents of the modelled watercourses where they increase to more than 1m^3/s.

Fluvial flood velocities along the Rumsam Stream are relatively high, on average greater than 0.5m^3/s. Adjacent to the River Taw by Bishops Tawton they are approximately 0.5 to 1m^3/s increasing locally to 2m^3/s in places. Velocities along the Muddle Brook and Fremington Stream also average between 0.5 and 1m^3/s.

As a result of the impacts of climate change on fluvial flood flows, velocities in the areas highlighted above are projected to increase by up to 0.8m^3/s. Where areas which previously did not experience flooding are now inundated, fluvial flood velocities are mostly less than 0.2m^3/s.

Tidal flood velocities at the 1 in 200 year (defended) event across Barnstaple are similar to those experienced during the 1in 100 year defended fluvial flood event, i.e. mostly lower than 0.1m^3/s. This is exceeded along Bradiford Water and at Pilton Park where velocities are recorded to increase to 0.3m^3/s and along Rumsam Stream which has maximum velocities of up to 1m^3/s.

Average tidal flood velocities are projected to remain low across most of the area in the future but where increases occur as a result of the effect of climate change on sea level rise, they are significantly higher than present day velocities. Table 5.4.1 details the projected changes in velocity by the years 2070 and 2115.

Table 5.4.1 - Changes in tidal flood velocity due to the effects of climate change

Location	Change in 1 in 200 year velocity (m^3/s)	
	By 2070 (change from current)	By 2115 (change from 2070)
Pottington Business Park	+1.2	-0.9
Pilton park	+0.1 - 2.5	+2.8
Rock Park adjacent to Taw	No change	+0.8 - 1.5 but rest of park is <0.1
Rumsam Stream	-0.3	+0.3
Along River Taw by Bishops Tawton	+0.75	+0.5
Between River Taw and A361 at Lake	No change	+1.8
Retail park at Anchorwood	+0.9	+3

5.5 Flood Hazard

As a consequence of the fluvial flood extents being relatively small for the current situation, depths are generally significant where flooding occurs. This is reflected by the fluvial hazard, which is significant to extreme in all locations where flooding was recorded to occur. This indicates that the fluvial flood hazard is mostly dependent on flood depth. Tidal flood hazard was generally found to be lower than fluvial, however by 2115 all flooded areas are categorised as having a hazard rating of extreme.

5.6 Areas Benefiting from Defences / Residual Risk Areas

As shown on the A1 maps provided in Appendix D, Areas Benefiting from Defences (ABDs) and Residual Risk Areas (RRAs) have been created as discussed in section 2. The largest areas of both fluvial and tidal ABD are located about Pilton Park and Pottington, Sticklepath and along the River Taw south of the Tarka Trail cycle path. The implications of a breach should be considered if development is to occur in an ABD area.

Breach analysis has been undertaken at Mill Road and alongside Pilton Park at Fair View car park. This showed that the breach opposite Pilton Park would result in the greatest amount of flooding extending rapidly into Pottington. Flooding from a breach at Mill Road is comparatively less due to the high ground behind the wall and narrow breach width modelled therefore limiting the amount of flow onto the floodplain. For more detailed analysis see the Motts modelling report which accompanies the model.

Both tidal and fluvial RRAs are quite extensive especially at Bradiford Water, Fremington, Rock Park and along the Taw from Lake to Bishops Tawton. The tidal RRA is in general greater in extent than fluvial in particular at Pilton Park and Sticklepath. RRA areas should be avoided when considering development.

5.7 Number of properties at risk

Figure 5.7.1 - Wards in the Level 2 SFRA study area

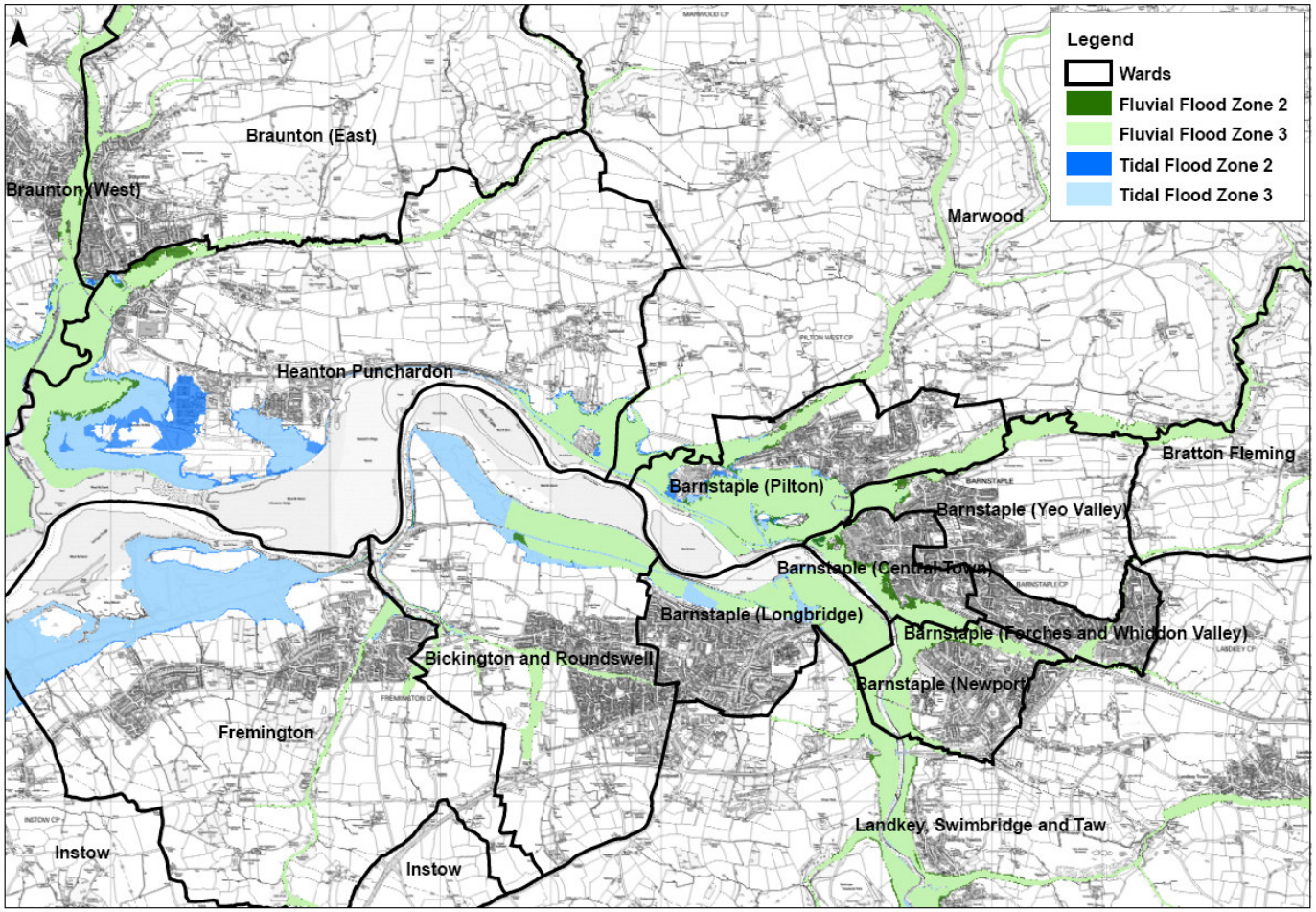

Table 5.7.1 - Number of properties across the Barnstaple area currently at risk from fluvial and tidal flooding by ward (based on the Environment Agency Flood Zones and Barnstaple 2D Modelling and Mapping study results)

	Number of properties									Percentage of properties in the ward at risk							
	Total	In FZ3		In FZ2		Current defended scenario		Climate change defended scenario		In FZ3		In FZ2		Current defended scenario		Climate change defended scenario	
Ward name		Fluvial	Tidal	Fluvial	Tidal	Fluvial	Tidal	Fluvial	Tidal	Fluvial	Tidal	Fluvial	Tidal	Fluvial	Tidal	Fluvial	Tidal
Barnstaple (Central Town) Ward	3,840	1,005	516	1,241	550	120	188	579	1,016	26%	13%	32%	14%	3%	5%	15%	26%
Barnstaple (Forches and Whiddon Valley) Ward	1,931	17	0	23	0	0	0	0	0	1%	0%	1%	0%	0%	0%	0%	0%
Barnstaple (Longbridge) Ward	1,982	179	156	182	163	1	115	2	181	9%	8%	9%	8%	0%	6%	0%	9%
Barnstaple (Newport) Ward	2,031	391	216	434	227	62	17	196	335	19%	11%	21%	11%	3%	1%	10%	16%
Barnstaple (Pilton) Ward	2,402	929	700	967	741	10	283	77	998	39%	29%	40%	31%	0%	12%	3%	42%
Barnstaple (Yeo Valley) Ward	1,992	394	329	477	374	4	4	4	459	20%	17%	24%	19%	0%	0%	0%	23%
Bickington and Roundswell Ward	2,172	29	1	32	10	15	7	18	20	1%	0%	1%	0%	1%	0%	1%	1%
Bratton Fleming Ward	14	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%	0%	0%
Fremington Ward	1,975	21	2	25	4	9	2	11	38	1%	0%	1%	0%	0%	0%	1%	2%
Heanton Punchardon Ward	624	8	8	8	8			3	158	1%	1%	1%	1%	0%	0%	0%	25%
Landkey, Swimbridge and Taw Ward	1,742	118	19	140	26	26	16	27	27	7%	1%	8%	1%	1%	1%	2%	2%
Marwood Ward	37	1	1	1	1	1	0	1	1	3%	3%	3%	3%	3%	0%	3%	3%
Totals	**20,742**	**3,092**	**1,948**	**3,530**	**2,104**	**248**	**632**	**918**	**3,233**	**15%**	**9%**	**17%**	**10%**	**1%**	**3%**	**4%**	**16%**

* For ward locations see Figure 5.7.1

Note: The number of properties may include some duplication because a proportion of properties may be at risk from both tidal and fluvial flooding and therefore may have been included in both property counts.

Table 5.7.1 details the number of properties at risk from fluvial and tidal flooding in the various Barnstaple wards. It shows that there is no risk to properties in the Bratton Fleming ward within the study area either currently or in the future and that there is minimal risk under current defended and undefended conditions or in the future as a result of the effects of climate change, to properties in the following wards:

- Bickington and Roundswell,
- Barnstaple (Forches and Whiddon Valley), this ward is currently protected by defences and the table indicates that in an undefended scenario, i.e. should the defences fail, only 1% of properties in the ward would become at risk from fluvial flooding (not tidal),
- Fremington,
- Heanton Punchardon (until 2115 when 25% of properties become at risk from tidal flooding),
- Marwood and
- Landkey, Swimbridge and Taw.

The Barnstaple (Yeo Valley) ward demonstrates the beneficial effect of defences on fluvial and tidal flood risk. Table 5.7.1 shows that for this ward no properties are currently at risk under defended conditions but without defences, represented by the extent of the EA Flood Zones, around 20% of properties become at risk from both fluvial and tidal flooding.

There are a significant number of properties at risk of flooding under the current defended scenario in the following wards:

- Barnstaple (Central Town),
- Barnstaple (Longbridge),
- Barnstaple (Newport) and
- Barnstaple (Pilton).

Climate change is anticipated to have a significant impact on fluvial and tidal flood risk to the properties of Barnstaple (indicated by increases in numbers at risk by between 10 and 30%) in the following wards:

- Barnstaple (Central Town),
- Barnstaple (Newport),
- Barnstaple (Pilton),
- Barnstaple (Yeo Valley) and
- Heanton Punchardon.

Note that the number and percentage of properties may include some duplication between those at risk of tidal and fluvial flooding.

The information in Table 5.7.1 can be used as a starting point to consider future flood defence priorities. The results of the Barnstaple 2D Modelling and Mapping study indicate that the Barnstaple (Central Town) and Barnstaple (Pilton) wards would benefit most from flood defence improvement. This is because these wards, both now and in the future have a significant percentage of existing properties at risk from tidal and fluvial flooding. This may indicate a need to improve the flood defences along the relevant reach of the River Taw and lower reaches of the River Yeo, specifically downstream of, and including, the Flood Storage Area at Pilton Park as highlighted by model results in section 4.11.4.

Although results indicate that the Barnstaple (Newport) ward has fewer properties at risk than the Central Town and Pilton wards, the number at risk of tidal and fluvial flooding by 2115 still amounts to over 500 properties. This suggests that the improvement of defences along the Coney Gut may also require prioritisation in the future, particularly along the lower reaches of the Coney Gut. This is because although the Coney Gut has a storm overflow channel and the flood storage area at Portmarsh field, fluvial and tidal climate change flood extents by 2115 indicate that this will be inadequate to defend the properties surrounding Portmarsh field and Rock Park from flooding in the future.

The Barnstaple (Yeo Valley) and Heanton Punchardon wards should also be considered for future flood defence prioritisation because although there are currently no properties at risk in these wards, model results suggest that up to 25% of properties in each ward will be at risk from tidal flooding by 2115 (see figures in Appendix D).

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of impact to proposed sites considered within this Level 2 SFRA

Section 3 provides a summary table of the flood risk to each site and the possible implications of increasing flood risk due to the development, along with details of the potential uses for the site. In general all sites are suitable for all types of development, at least in part, although the sequential approach should be applied within each site when determining the site layout. This is due to variations in flood risk across some of the sites. Individual site recommendations can be found in Section 4.

6.2 Summary of impact of development elsewhere

In general, the impact of development at the potential sites on the areas surrounding them is considered to be low provided any additional surface water is managed appropriately. There are, however a number of sites where flood risk becomes significant when the effects of climate change are taken into account. These sites are primarily in the town centre of Barnstaple and will require further investigation with regard to the modelling of breaches in flood defences and the consequences of infilling the floodplain before development is pursued. All new development, green or brownfield, **will have to** install a SuDS system.

Section 5 highlights flood risk indicated by the model results for the rest of the Barnstaple area. Generally, fluvial flood risk is currently greater than tidal flood risk, although the risk of tidal flooding is still significant. However due to the effects of climate change, tidal flooding is anticipated to become a much greater risk than fluvial in the future.

Overall, as highlighted at the beginning of section 5, the area which experiences the most severe flooding is located between the watercourses of Bradiford Water and the River Yeo, incorporating Pottington and Pilton. Residential development would not be appropriate at these locations due to the low onset of flooding. Other areas where this applies include the land west of Bradiford Water at Ashford, land in the vicinity of Rock Park and Portmarsh Lane, selected areas at Sticklepath, at Lake and along The Strand. This could impact the potential for development at sites BAR1b/c, BAR1g, BAR1i and Seven Brethren.

Where flooding does not occur until the 1 in 200 year tidal event in 2115, Less Vulnerable (including commercial) development may be appropriate. This relates in particular to the areas of Pottington Business Park (by site BAR1b/c), small areas of Pilton such as in the vicinity of the college, in the locale of Yeo Vale Road and parts of Sticklepath (adjacent to the Seven Brethren site).

Outside of the areas mentioned above all types of development are suitable on flood risk grounds providing that relevant and appropriate site specific flood mitigation measures are incorporated. This includes the areas of Newport, Rumsam, Bickington, Fremington, Derby, the area between Raleigh and Bradiford and parts of the town centre. It is suggested that due to the future fluvial and tidal flood risk, both the 1 in 100 year plus climate change fluvial extent and the 1 in 200 year plus climate change (to 2115) tidal extents displayed on the A1 maps in Appendix D are considered when planning future development allocations in the vicinity of the Rivers Yeo, Taw and Coney Gut.

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