4 Flood risk in Adur and Worthing

4.1 Introduction

The Adur and Worthing SFRA update is undertaken for the entire area within the administrative boundaries. There are three designated main rivers, and a number of ordinary watercourses, within Adur and Worthing, and the area shares approximately 16km of its boundary with the sea. Underlying geology is dominated by chalk downland, the highly permeable nature of this bedrock contributes a risk of flooding through emergent groundwater.

Adur and Worthing are affected to varying degrees by all sources of flooding, including surface water, fluvial, tidal, sewer and groundwater. This section provides a summary of flood risk across Adur District and Worthing Borough.

4.1.1 How flood risk is assessed

A flood is now formally defined in the Flood and Water Management Act (2010).

A flood is defined by the act as "any case where land not normally covered by water becomes covered by water". The act also states that a flood, as defined above, can be caused by:

(a) heavy rainfall

(b) a river overflowing or its banks being breached

(c) a dam overflowing or being breached

(d) tidal waters

(e) groundwater

(e) anything else (including any combination of factors).

In the context of the FWMA (2010) a flood does not include:

(a) A flood from any part of a sewerage system, unless wholly or partly caused by an increase in the volume of rainwater (including snow and other precipitation) entering or otherwise affecting the system.

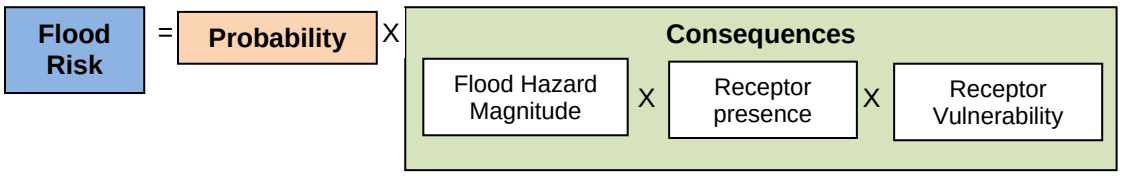
(b) A flood caused by a burst water main (within the meaning given by section 219 of the Water Industry Act 1991).

The FWMA (2010) states that flood risk *"means a risk in respect of flood", where risk is "assessed and expressed (as for insurance and scientific purposes) as a combination of the probability of the occurrence with its potential consequences".*

Thus it is possible to define flood risk as:

Flood Risk = (Probability of a flood) X (scale of the consequences)

On that basis it is useful to express the definition as follows:



4.2 Fluvial flood risk

4.2.1 Introduction

This section assesses risk in Adur and Worthing from fluvial flooding, now and in the future. It makes use of all the data and information described in Section 2. It defines the fluvial Flood Zones 1, 2, 3a and 3b, providing enough information for the Councils to perform the Sequential Test for these areas.

Flood Zones 1, 2 and 3 delineate areas at low risk, medium risk and high risk respectively from both tidal and fluvial flooding. Environment Agency Flood Maps, detailing Flood Zones 2

and 3, do not take into account the effects of flood defences, and as such provide a worst case assessment of flood risk. The delineation of flood zone 3b does take account of flood defences. The effects of fluvial defences in Adur and Worthing are described in Section 4.2.2.

4.2.2 Fluvial flood risk

Fluvial flooding is caused by high flows in rivers or streams exceeding the capacity of the river channel and spilling onto the floodplain, usually after a period of heavy rainfall.

The SFRA (2008) defined fluvial flood risk using the series of hydraulic models which were developed for the Environment Agency CFMP. These models were considered more detailed than the Environment Agency Flood Zones, therefore the results were used to delineate the Flood Zones. Flood Zone 3b was defined using the CFMP models, with defences for the 5% AEP flood event, where CFMP models were not available, Environment Agency Flood Zone 3a was used instead. The Fluvial Flood Zones for Adur and Worthing have been defined using the modelling undertaken for the SFRA (2008).

The only area that has been updated since the SFRA was completed is the Shoreham Harbour area south of the A27. As part of the Shoreham Harbour Study (2011) the fluvial Flood Zone 3b (1 in 20 year fluvial event accounting for the effect of existing defences) was remodelled. The delineation of the Flood Zones is shown on Map 4 (Appendix A), the map has been coloured to clearly show the where different data sets have been used to define the Flood Zone 3b.

The following sections briefly describe fluvial flood risk areas by watercourse.

River Adur

The fluvial flood risk from the River Adur was assessed using the SFRA (2008) data, except for the region south of the A27 where detailed modelling outputs from the Shoreham Harbour study has been used to update the Flood Zone 3b.

The largest areas of Flood Zones 2 and 3a are along the River Adur as the river is the largest in the study area and the land adjacent to the river channel is flat, allowing flood flows to spread out. The Flood Zone 3b is generally contained to the channel due to the presence of defences along the length of the River Adur.

Teville Stream

There was no new data available for Teville Stream at the time of writing. There is an ongoing Environment Agency Flood Mapping Study of the Teville Stream, but the outputs were not available in time for this SFRA update. Consequently, the fluvial flood risk was assessed using the SFRA (2008) data. The Teville Stream was modelled using the CFMP TUFLOW model updated as part of the SFRA (2008) with LIDAR data. The SFRA (2008) highlighted that there was low confidence in the results of this model. Consequently, any future development proposals near the Teville Stream should consult the most recent data (likely to be the new Environment Agency Flood Risk Mapping Study) when assessing flood risk.

The fluvial flood zones along the Teville Stream are clearly defined, and generally remain in bank for all return periods up to 1 in 1000 year (Flood Zone 2) along most of the channel. The only notable area of flooding occurs to the north of the Teville Stream, (within the Adur area) to the southwest of Sompting and the east of Decoy Farm. This appears to be due to flood flows being constrained by the railway embankment, which crosses the valley at this point.

Ferring Rife

There is no new data identified for Ferring Rife, therefore fluvial flood risk was assessed using the SFRA (2008) data. The Ferring Rife was modelled using the CFMP TUFLOW model updated as part of the SFRA (2008) with LIDAR data. The SFRA (2008) considered the model results of the Ferring Rife to be appropriate for use in this level of study.

The flood zones appear clearly defined with an extensive Flood Zone 3b. The flood zones show the area north of the A2032 at Yeoman Way and Southern House to be at risk of flooding, as well as part of the Northbrook College site. The residential area southwest of the A2032 towards May Bridge on the A259 is also shown to be at flood risk, including: Boxgrove, The Greenway, Patching Close, The Strand and Coleridge Close.

4.2.3 Fluvial functional floodplain

Flood Zone 3b indicates the 'functional floodplain', which is defined as an area of land where water has to flow or be stored in times of flood. This is usually taken to be the 1 in 20 year event taking into account the effects of defences and other flood risk management infrastructure. However, the practice guide also states *"developed areas are not generally part of the functional floodplain"*, yet:

"some developed areas may still provide an important flood storage and conveyance function, such as a car park that has been designed to flood periodically to preserve flood storage volumes at a riverside commercial development. Roads and other linear spaces can act as flow routes and the functionality of such areas should be considered when defining Flood Zones."

For the purposes of this SFRA the functional floodplain is defined as the defended 1 in 20 year flood extent. Amendments to the delineation of Flood Zone 3b in Adur and Worthing have been made to the River Adur south of the A27, following the Shoreham Harbour Study (2011). However, it should be noted that the differences between the SFRA (2008) fluvial Flood Zone 3b in this area and the new fluvial Flood Zone 3b are minimal.

Along the River Adur the modelling undertaken has shown, taking into account the effects of existing defences, the area south of the A27 does not convey or store flood flows from the perspective of fluvial flooding alone. The only area along the River Adur where storage or conveyance is operational in the 1 in 20 year defended case is the small low-lying area north of the A27 around Coombes Road. From an assessment of the OS mapping and the nature of land use in the area (a series of drainage networks and playing fields) it is apt that this area be defined as being 'functional'.

The Teville Stream flood zone mapping shows the area to the southwest of Sompting and the east of Decoy Farm designated as Flood Zone 3b. From an assessment of the OS mapping and the nature of land use in the area (a series of drainage networks and open land), it is apt that this area be defined as being 'functional'.

The Ferring Rife Flood Zone 3b extends from Yeoman Way and Southern House including part of the Northbrook College site across the A2032 and the residential area towards May Bridge on the A259 (covering Boxgrove, The Greenway, Patching Close, The Strand and Coleridge Close, and then west towards the border with Arun. The Yeoman Way - Southern House area and the residential area between the A2032 and May Bridge are well developed, as such in line with the comments made in the PPS25 practice guide (above) the actual 'functionality' of the area could be questioned. However, detailed hydraulic modelling would need to be undertaken to prove the area did not offer any storage or conveyance for floodwaters. The undeveloped open space along the remainder of the Ferring Rife Flood Zone 3b suggests these areas act 'functionally' in time of flood.

4.2.4 Fluvial defences

There are defences along both banks of the River Adur through the study area. The defences on the River Adur upstream of Shoreham Harbour are predominantly earth embankments. According to the Rivers Arun to Adur Flood and Erosion Management Strategy[9] "*the defences on the west bank are mostly maintained by the Environment Agency and provide a very low standard of protection with the possibility of regular overtopping and defence failure*". The defences of the River Adur through Shoreham Harbour include steel sheet piling, concrete walls, rock revetments and a shingle beach at Kingston Beach. The SFRA (2008) stated the SoP of these defences was 3.3 % upstream and 0.5% downstream of Shoreham Bridge. It is unclear as to whether the bridge referred to is the A27 or not although the statement appears to be consistent with what is shown in Map 5 (Appendix A).

There are no formal raised defences along the Teville Stream or Ferring Rife within the study area. However, Brooklands Lake is situated on the Teville Stream at its coastal outlet, and acts as a balancing pond and provides storage during tide-locking.

Map 5 and Map 16 (Appendix A) show the location of the defences through Adur and Worthing, and shows the actual flood risk from a 1 in 100 year fluvial event, accounting for the

[9] Rivers Arun to Adur flood and erosion management strategy 2010 - 2020 (Environment Agency, April 2010)

effect of defences. From viewing Map 5 it is clear the largest area which benefits from the fluvial defences is the Shoreham Airport - Lancing area on the west bank of the River Adur.

4.2.5 Fluvial residual risk

'Residual risk' is defined as the flood risk remaining with flood mitigation measures in place. The land behind the defences is only at risk of flooding through failure or overtopping of the defences.

Flood zones represent the undefended situation and can therefore be used to inform the scale of the residual risk from failure of a defence. Based on Flood Zone 3a, the Shoreham Airport - Lancing area on the west bank of the River Adur is shown to be at risk of a failure and overtopping of the defences.

In most instances in the study area, raised flood defences serve to protect land against both fluvial and tidal flooding. In these cases fluvial and tidal residual risk is often co-incident (Section 4.3.5). Development proposals in these areas would be required to consider further the extent and nature of residual risk and appropriately mitigate it.

4.2.6 Effects of climate change on fluvial flood risk

The effect of climate change on fluvial flood risk in Adur and Worthing has been assessed using the climate change results from the SFRA (2008).

The climate change modelling undertaken in the SFRA (2008) applied a 20% increase in flows for both epochs (2056 and 2106). The mean spring tide for the downstream boundary was varied accordingly for each epoch to represent the increases in sea level rise over time (367mm for 2056, and 1030mm for 2106). Consequently, only those areas that are tidally influenced vary between the two climate change epochs, as seen in Map 6 (appendix A). The main areas shown to be affected by fluvial flooding in the future are the tidally influenced areas around Shoreham-by-Sea and South Lancing.

Where there was no modelled climate change outline from the SFRA (2008), Flood Zone 2 should be used to represent future flood extent.

New climate change guidance

The new climate change advice note "Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities" was issued by the Environment Agency in September 2011[10]. The potential changes in river flows and sea level rise suggested correspond to the various emission scenarios stated in UKCP09. They range from the highest H++ emissions scenario to the low emission scenario. The medium emission scenario corresponds to the 'change factor', equivalent to the average predicted change. The guidance recommends that *"when considering climate change a full appreciation of emission scenario and climate uncertainty is taken into account. The upper and lower end estimates are designed to achieve this within flood and coastal erosion risk management applications."* It would be appropriate to consider the upper H++ scenario when reviewing some planning applications, for example critical infrastructure which could not readily be moved or protected in the event of climate change occurring at a rate beyond what is expected.

The existing estimates of the impact of climate change have used a 20% increase in river flows. This is within the bounds of the change factor up to the 2050s (Table 4.1) however in the future the change factor increases to 30%. The sea level rise calculated for 2056 in the SFRA (2008) is equivalent to the upper end estimate in Table 4.2; the level used for the 2106 scenario was less. For the purposes of this SFRA it was felt that the existing estimates were sufficient to provide an overview of the potential future risk across the area and to inform the Sequential Test of proposed sites. However, if more detailed modelling is undertaken in the future in support of a planning application it is recommended that regard is given to the latest climate change values available.

[10] Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities (Environment Agency, September 2011)

Table 4.1: Future changes in river flows for catchments in the South East of England[10]

	Total potential change anticipated for the 2020s	Total potential change anticipated for the 2050s	Total potential change anticipated for the 2080s
SE England			
Upper end estimate	30%	55%	100%
Change factor	10%	20%	30%
Lower end estimate	-15%	-5%	0%
H++	40%	70%	125%

Table 4.2: Future changes in sea level

	Sea level rise mm/yr up to 2025	Sea level rise mm/yr 2026 to 2050	Sea level rise mm/yr 2051 to 2080	Sea level rise mm/yr 2081 to 2115
H++ scenario	6	12.5	24	33
Upper end estimate	4	7	11	15
Change factor	Use UKCP09 relative sea level rise medium emission 95% projection for the project location available from the user interface.			
Lower end estimate	Use UKCP09 relative sea level rise low emission 50% projection for the project location available from the user interface.			

4.2.7 Flood warning system

The Environment Agency operates a flood warning service covering fluvial flooding for Adur and Worthing using its Flood Warnings Direct System. These areas are currently under revision by the Environment Agency to bring them up to date with guidance released in the last few years by making them more community orientated.

There is currently one flood warning area covering fluvial flood risk in the Adur and Worthing Study Area:

071FWF5301 - the Ferring Rife at North Ferring, including the Goring, A259 at Northbrook College, Ferring Lane, Highdown Way, Langbury Lane, and Downview Avenue. There are also four tidal flood warning areas, some of these cover the Teville Stream and the River Adur areas, see Section 4.3.8 for details.

4.3 Tidal flood risk

4.3.1 Introduction

This section assesses risk in Adur and Worthing from tidal flooding, now and in the future. It makes use of all the data and information described in Section 2. It defines the tidal Flood Zones 1, 2, 3a and 3b, providing enough information for the Councils to perform the Sequential Test for these areas.

Worthing's coastline extends from Ferring in the west to Lancing in the east, Adur's coastline then extends from Lancing to Shoreham Port in the east. Much of the area at risk from tidal flooding is protected by flood defences. However, there remains a residual risk that the defences could fail or be overtopped during a flood event.

4.3.2 Tidal flood risk

Tidal flood risk is assessed based on Extreme Still Water Sea-levels (ESWSL). An ESWSL is the level the sea is expected to reach during a storm event for a particular return period as a result of the combination of tides and surges. As these levels are based on 'still' water, the affect of short-term fluctuations in sea-level associated with wind and swell waves are not included.

In line with the approach agreed for the recent Arun to Adur Flood Risk Mapping Study, wave overtopping will be considered in this SFRA update within the assessment of actual risk or residual risk, not within the flood zone delineation. This approach balances the predominance of redevelopment and regeneration in the coastal frontage of the study area with the need to consider flood risk from all sources. Allowing for wave-overtopping increases the extent of flooding. In some instances, this can mean the defended 1 in 200 year outline with the effect of wave overtopping would be larger than the Flood Zone 3a tidal extent. Map 10 and 11 (Appendix A) demonstrate the effect of wave overtopping on the tidal flood extents at 0.5% AEP and 0.1% AEP respectively. The affect of wave overtopping is discussed further under Section 4.3.5. However, the nature of this flooding is very different from inundation arising from still water level flooding. Wave overtopping can lead to increases in volume of inundation, speed of inundation and overall hazard.

Tidal flooding is caused by extreme tide levels exceeding ground levels. Flood Zones 1, 2 and 3 delineate areas at low risk, medium risk and high risk respectively from both tidal and fluvial flooding. These flood zones do not take into account the effects of flood defences, and as such provide a worst-case assessment of flood risk. The delineation of the tidal flood zones and the areas of Adur and Worthing, which are within tidal flood zones are shown on Map 7 (Appendix A). The flood zone delineation north of the A27 is from SFRA (2008) modelling. Elsewhere the delineation uses the results from the recent Environment Agency studies: 'Arun to Adur Flood Modelling' (2011); and 'Shoreham Harbour Regeneration: Design and Flood Risk Study' (2011).

In Worthing the main areas to be shown at tidal flood risk by the flood zones is the Brooklands Pleasure Ground and the area from Alinora and Marine Crescent to the West Parade. Along the remainder of the coastal frontage, the flood zones are confined to the beach.

In Adur, the tidal flood zones are more extensive, covering parts of South Lancing, Shoreham by Sea, Shoreham Harbour and Shoreham Airport. The tidal flood zones continue north of the A27 along the River Adur.

4.3.3 Tidal functional floodplain

Flood zone 3b indicates the ‘functional floodplain’, which is defined as an area of land where water has to flow or be stored in times of flood. This is usually taken to be the 1 in 20 year event taking into account the effects of defences and other flood risk management infrastructure see Map 7 (appendix A). However, the practice guide also states *"developed areas are not generally part of the functional floodplain"*, yet:

"some developed areas may still provide an important flood storage and conveyance function, such as a car park that has been designed to flood periodically to preserve flood storage volumes at a riverside commercial development. Roads and other linear spaces can act as flow routes and the functionality of such areas should be considered when defining Flood Zones."

The question as to whether the area delineated as flood zone 3b, and therefore 'functional floodplain', actually acts functionally has arisen in the past. To argue that an area, regardless of size, is not ‘functional’ there is a need to demonstrate the area does not provide a *flood storage or conveyance function.*

The recent Shoreham Harbour Regeneration: Design and Flood Risk Study undertook an investigation around the Shoreham Harbour regeneration area (one of the Core Strategy sites) to determine whether those areas within the 1 in 20 year extent act functionally. An option, "River/Canal Flood Defence Option A", was modelled which looked at the impact of defending the Shoreham Harbour regeneration ‘Development Areas’. The scenario modelled flood walls in the Shoreham Harbour regeneration area with a crest level of a 0.5% AEP tidal event. When the results from this were compared to the defended 1 in 20 year event it showed that the "presence of the Development Areas and their defences, for the most part, do not increase flood levels by more than 0.01m". A small area on the south bank of the river adjacent to the development area was shown to experience a localised increase in the flood level of up to 0.05m. However, the study determined that "on the whole, the Development Areas do not provide significant storage or conveyance potential which materially impacts flood risk elsewhere". As a result, the area is no longer considered 'functional'.

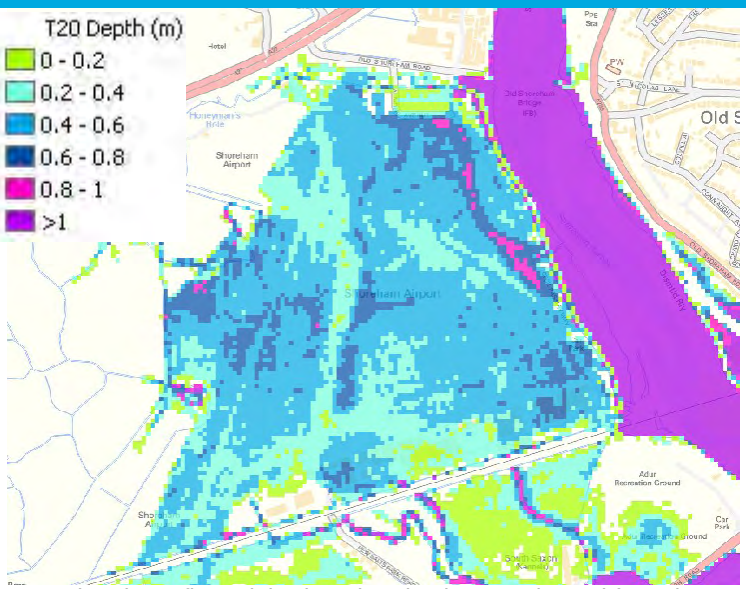
This area of non-functionality has been shown on Map 7 as a 'cross-hatched' polygon.

The functionality of the area shown to inundate during the 1 in 20 year event at Shoreham Airport, Old Shoreham and some of the land immediately north of the Hasler estate is also open to question.

In 2010 an investigation was undertaken which contested the designation of the Shoreham Airport site as 'functional floodplain' (detailed in chapter 2.2.4) which was based on probability of inundation alone.

Results from the most recent and detailed modelling of the area undertaken as part of the Shoreham Harbour Regeneration study are compared to the conclusions drawn from the 2010 investigation in Table 4.3.

Table 4.3 Comparison of studies covering Shoreham Airport

WSP Shoreham Airport 1 in 20 modelling Conclusions	Results from Shoreham Harbour Regeneration: Design and Flood Risk Study
The site only experienced short duration shallow flooding. The defence overtopping in the 1 in 20 year event occurred for a length of time of 0.5hours, with the peak level above the defence being 0.04m.	 From the above figure it is clear that depths experienced from the overtopping of defences are generally around half a metre deep and in places deeper. This contradicts the conclusion of the WSP study that suggests the area only experiences 'shallow' flooding.
A 20m grid resolution applied for the model means that a larger area (20mx20m) would be shown as wet even with a small volume of flood water.	A 10m x 10m grid resolution was used for the Shoreham Harbour Regeneration study modelling. Inundation depths are shown above.
A long drainage ditch appeared to be present immediately behind the flood defence, which was not reflected in the SFRA model. This drainage ditch could potentially collect and divert floodwater which spills over the defences	The recent TUFLOW model uses a more detailed grid resolution and up to date LIDAR data for the area, so would have better represented the floodplain drainage networks.

Additionally, recent modelling to test the effect of building the west bank Adur Tidal Walls showed that if the walls were built along the west bank the depth of flooding, and hence risk, increases on the east bank[6].

This information suggests that the west bank area of the Adur (including Shoreham Airport) provides a degree of storage at present and should, based on the evidence available, be considered functional.

However, the Adur Tidal Walls scheme will improve the defences along the west bank and the standard of protection afforded to the area. Following construction the area will no longer be inundated during the 1 in 20-year flood event, the extent of the area no longer inundated is shown in Map 17 (Appendix A). Consequently, in the future it will be appropriate for this area to be considered non-functional and will lead to the redefinition of Flood Zone 3b. It is understood that the impact of the scheme on flood risk on the east bank will be mitigated through local improvements to the east bank defences. *At the time of writing the scheme had yet to be ratified and the funding secured.*

The Old Shoreham area, along Freehold Street to The Meads, is also shown to flood with a probability of 1 in 20 years or greater. However this area will benefit from the east bank defence improvements.

It is noted that a small stretch of the east bank, downstream of Norfolk Bridge and immediately to the west of the Shoreham Harbour regeneration area, is shown to suffer inundation in the 1 in 20-year event. This area is similar to the regeneration area in that it is currently developed land and is adjacent to the High Street within Shoreham town centre. The practice guide advises that "developed areas are not generally part of the functional floodplain". Neighbouring land around Shoreham Harbour was shown to not act functionally in time of flood and it is feasible that this small stretch would also not act functionally. In light of the current land use and the fact that PPS25 allows flexibility to make allowance for local circumstances it is reasonable for this area not to be defined as flood zone 3b.

The other significant areas shown to be within flood zone 3b (the Coombes Road area north of the A27, and the Adur recreation ground / South Saxon north of the Brighton Road) are areas of low-lying open space, with some recreational use, therefore it is deemed apt that these areas be defined as functional floodplain.

It should also be noted that the coastal frontage in Worthing and from South Lancing to Portslade-by-Sea (Shoreham Harbour) in the Adur and Worthing plan areas suffers from wave overtopping. Wave overtopping is not considered in the delineation of the functional floodplain. It is important that wave overtopping is considered when making land use planning decisions (section 2.2.4). The effect of wave overtopping should therefore be investigated thoroughly in flood risk assessments accompanying development applications in these areas. The allocation of land uses within these areas should be made on a sequential risk basis and suitable mitigation measures incorporated to manage the affects of wave overtopping where this cannot be avoided. Wave overtopping should be managed effectively through the design of development.

4.3.4 Tidal defences

The Adur and Worthing seafront is protected from tidal flooding by formal defences. The beaches along the coastal frontage consist of managed shingle ridges controlled by groynes. The tidally dominated River Adur, including Shoreham Harbour, is lined with formal defences on both banks. The defences along the River Adur vary in type, condition and standard of protection. The defences along the River Adur include earth embankments, steel sheet piling, concrete walls, rock revetments and a shingle beach at Kingston Beach.

The previous SFRA stated, "The standard of protection along the River Adur ranges from 0.2% annual probability event (1 in 500 year chance of flooding) from the Old Toll Bridge to the A27 to a considerably lower standard for the remainder of the defences". Yet the "coastal defences are in the main part constructed to offer protection from the 0.5% annual probability of exceedance event (1 in 200 year)". Table 4.4, provides a detailed breakdown of those defences, which prevent flooding from the sea.

The location of the extensive tidal flood defences in Adur and Worthing is shown on Map 8 and 16 (Appendix A).

Table 4.4: Defences to prevent flooding from the sea

Source: SFRA (2008) Volume 2, Table 4.4

River/Coastal Section	Main Defence	Design Standard	Standard of protection assessed from modelling
Toll Bridge – A27 Flyover	Concrete floodwalls and flood gate	0.20% (1 in 500)	Right Bank - > 0.1% (1 in 100 year) Left Bank - < 5% (1 in 20 year)
Shoreham Airport boundary with River Adur	Earth embankments and pre-cast concrete slab along crest in places.	5% (1 in 20)	< 5% (1 in 20 year)
Shoreham Harbour/Adur Estuary	Harbour arms Piecemeal defences consisting of sections of steel sheet piling, concrete wall, shingle beach, groynes and quaysides.	Variable but design standard approximately 2% (1 in 50)	< 5% (1 in 20 year)
Lancing Brook at Shoreham Harbour	Two flapped outfalls	2% (1 in 50 year)	< 5% (1 in 20 year)
Norfolk Bridge to Railway viaduct	The new Ropetackle development in Shoreham involved new defences being constructed along this section of the river	unknown	> 0.1% (1 in 100 year)
Emerald Quay to footbridge	Rear boundary walls of residential properties along Riverside Road. Mix of brick, concrete, timber and sheet steel piled walls.	50% (1 in 2)	< 5% (1 in 20 year)
Worthing and Adur Coastline	Coastal defence consists mainly of shingle beach, groynes, rock revetment and the western harbour arm.	0.5% (1 in 200)	> 0.1% (1 in 1000 year)
Teville Stream – River Adur	Groyne stabilised shingle beach Harbour arms prevent beach loss by longshore drift.	1%	> 0.1% (1 in 1000 year)
Eastern edge of Southwick to Arun river mouth	Coastal defence consists mainly of shingle beach, groynes, rock revetment and the western harbour arm.	0.5% (1 in 200)	> 0.1% (1 in 1000 year)
Ferring Rife – Teville Stream	Groyne stabilised beach Sea wall Grand Ave – George V Ave Sea wall at Splash Point Sea wall at New Parade Sea wall Ham Rd Tide flapped outfall on Ferring Rife and Teville Stream	0.5 % 0.5% 0.5% 0.5% 0.5%	> 0.1% (1 in 1000 year)

New Proposed Defences - Adur Tidal Walls

The Adur tidal walls are proposed to cover a long stretch of the west bank of the River Adur from the A27 road bridge in the north through to Shoreham Fort. It is suggested that these walls will be continuous apart from a short section close to the Adur Recreation Ground, where the Brighton Road embankment is high enough to form part of the defence line. It is proposed that the Adur Tidal Walls will be constructed to a height which will provide a SoP of 0.5% (1 in 200 year). As a consequence the land currently designated Flood Zone 3b may be changed to Flood Zone 3a (See Section 4.3.3). From information provided during the preparation of this SFRA it is suggested that the SoP of these defences will decrease under the impacts of climate change with some inundation of the floodplain behind the defences expected in a future (2115) 1 in 200 year return period event. Although it has been suggested that this inundation *"results principally from "back door flooding" over the A27 road embankment rather than significant overtopping of the Adur tidal walls themselves*.

New Proposed Defences - Other

A series of "redevelopment walls" will potentially be constructed in the Shoreham Harbour Regeneration area to protect the development areas under consideration as part of the Shoreham Harbour Regeneration Scheme. It is suggested that these walls will be built to provide a SoP to protect the areas from flooding during a 200-year return period extreme sea-level event based in the year 2115.

Further defences are proposed as part of the Ropetackle North development in Shoreham. These "Ropetackle defences" are suggested to provide flood protection for the site, areas on the east bank of the river in the vicinity of West Lake and The Meads, and some parts of Shoreham Town. The Ropetackle defences will not mitigate flooding to the town which might arise as a result of the overtoppping of the embankments north and south of Ropetackle.

Also a newsletter released by the Environment Agency[11] in October 2011 states that they are looking into how they "will improve the flood defences on the east bank of the River Adur at Shoreham".

4.3.5 Tidal residual risk

'Residual risk' is defined as the flood risk remaining with flood mitigation measures in place. The land behind the defences is only at risk of flooding through failure or overtopping of the defences.

Failure of flood defences

Flood zones represent the undefended situation and so allow consideration as to the extent of residual risk arising from failure of a defence. Map 8 (Appendix A) shows the comparison between the defended 1 in 200 year flood extent and the undefended flood extent (Flood Zone 3a).

In Worthing the main areas to be shown at residual flood risk are the Brooklands Pleasure Ground and the area from Alinora and Marine Crescent to West Parade.

In Adur, the only area along the coastal frontage shown to be at residual flood risk is the recreation ground to the east of Pen Hill south of the Brighton Road. The remainder of residual risk in Adur is associated with the extensive formal defences along the length of the River Adur.

The impact of a failure in the defences has not been modelled as part of this SFRA. The SFRA (2008) looked at two breach locations in Worthing consistent with the two areas shown to be at residual risk mentioned above. The extents from these breach analyses were consistent with the Flood Zone 3a outline.

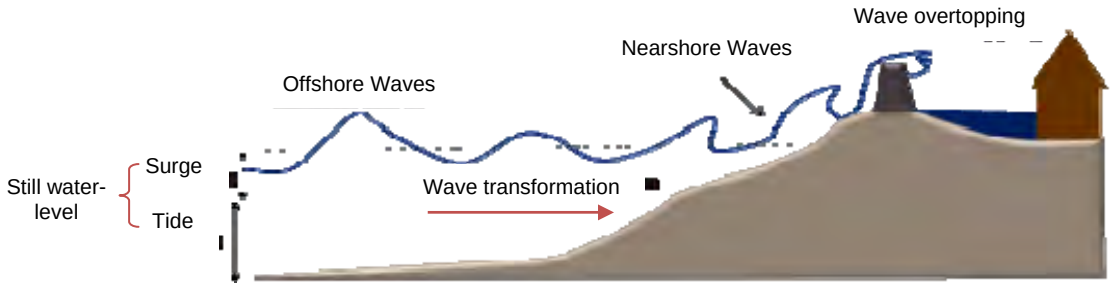
Any future development proposal shown to be in an area of residual risk should fully assess the risk as part of an FRA.

11 EA (October 2011) Shoreham east bank newsletter http://www.environment-agency.gov.uk/static/documents/Leisure/Adur_newsletter-oct_2011FINAL.pdf

Wave Overtopping

Tidal flooding along much of the south coast is characterised by the presence of risk associated with wave overtopping. In exposed locations along the coast, landward flooding is more likely to occur because of wave overtopping over inundation. Wave overtopping is a term, which encompasses a number of complex physical processes, which result in the transfer of water from the sea onto the coastal floodplain. The amount of wave overtopping that occurs during an extreme event is dependent on the local water depth, the properties of incoming waves and the geometry of local flood defences. Figure 4.1 outlines the process of wave overtopping in relation the Extreme Still Water Sea-level.

Figure 4.1: Illustration of residual risk associated with wave overtopping



Wave overtopping is one of the principal mechanisms of flooding for the coastal frontage. The Shoreham Harbour and Adur to Arun Study undertook modelling to identify the effect of wave-overtopping. Maps 10 and 11 (Appendix A) compare the effect of wave overtopping in the 1 in 20 year and 1 in 200 year events. The outlines for both return periods are significantly more extensive along the entire coastal frontage of Adur and Worthing. The effect of wave overtopping has not been included in the flood zone delineation. However, wave overtopping is of material concern to the coastal frontage, therefore any future development proposal should be accompanied by a flood risk assessment which appropriately considers the effects of wave overtopping.

4.3.6 Recent Coastal Flood Boundary study

Since the SFRA was completed a new Defra/Environment Agency project has been undertaken to determine extreme sea levels for the UK, published by the EA in February 2011 as "Coastal Flood Boundary Conditions for UK Mainland and Islands". Table 4.5 shows how the levels have changed from those used in the EA Adur to Arun Flood Mapping Study.

Table 4.5 shows that in general the new extreme sea-levels are lower than those used for the Adur to Arun study. However the differences between them is not thought to be significant enough to warrant remodelling the flood risk as the new levels are within the confidence level of ±300mm.

Table 4.5: Difference in Extreme Sea Level (mAOD)

2011[12] (new) minus 2010[13] (previous)

Return Period	Littlehampton	Worthing	Shoreham
20	-0.15	-0.14	-0.10
75	-0.21	-0.10	-0.06
200	-0.19	-0.08	-0.04
1000	-0.19	-0.08	0.05

4.3.7 Effects of climate change on tidal flood risk

The Arun to Adur Flood Modelling and the Shoreham Harbour Regeneration: Design and Flood Risk Study (2011) undertook detailed modelling of the effect of climate change on tidal

[12] Coastal Flood Boundary Conditions for UK Mainland and Islands, Project: SC060064/TR2: Design sea levels, February 2011

[13] Extreme Sea-levels: Kent, Sussex, Hampshire and the Isle of Wight, Updated Summary Report, July 2003

flood risk through Adur and Worthing. Details of the climate change effect on tidal flood risk within Adur and Worthing are shown in Map 9 (Appendix A).

In Worthing the coastal frontage from Arlington Avenue in the east to Bernard Road in the west and the Marine Parade from South Street to Warwick Road are shown to be at risk of flooding in the future (2115). The modelled outputs shown on Map 9 (Appendix A) take account of defences therefore it can be assumed this inundation would be because of the sea level exceeding the level of the coastal defences.

In Adur the present day 1in 200 year defended extent is extensive due to the current standard of protection of the defences being exceeded. In the future this extent increases further (see Map 9, Appendix A). The areas shown to be at risk in the future are:

- Lancing area bounded by the railway, A2025 (Grinstead Lane) and the A27;
- north of Old Shoreham Road;
- Old Shoreham around Connaught Avenue, Victoria Road and Ropetackle; and
- Shoreham Harbour, around Shoreham town centre, Southwick and Shoreham Beach.

The effect of climate change on wave overtopping has not been looked at as part of the existing studies. Given that the region is highly susceptible to wave overtopping, it should be noted that the true risk of future climate change is only partially presented.

New climate change guidance

The new climate change advice note is described in the Section 4.2.6.

The existing estimates of climate change are within the bounds of this new guidance. However, it should be noted that the guidance recommends that "when considering climate change a full appreciation of emission scenario and climate uncertainty is taken into account. The upper and lower end estimates are designed to achieve this within flood and coastal erosion risk management applications." It would be appropriate to consider the upper H++ scenario when reviewing some planning applications, for example critical infrastructure which could not readily be moved or protected in the event of climate change occurring at a rate beyond what is expected.

The sea level rise calculated for 2070 and 2115 as part of the recent EA studies in the SFRA (2008) are equivalent to the change factor suggested and only slightly less than the upper end estimate in Table 4.2. For the purposes of this SFRA it was felt that the existing estimates were sufficient to provide an overview of the potential future risk posed to the area and to inform the Sequential Test of proposed sites.

4.3.8 Flood warning systems

The Environment Agency operates a flood warning service covering tidal flooding for Adur and Worthing using its Flood Warnings Direct system. These areas are currently under revision by the Environment Agency to bring them up to date with guidance released in the last few years by making them more community orientated.

There are currently four flood warning areas covering tidal flood risk in Adur and Worthing:

- 073FWC11A - coastline at Portslade, Shoreham by-Sea, Hove and Brighton, including Shoreham Port and Brighton Marina.
- 071FWC3001 - coastal areas of Shoreham by Sea, including Shoreham beach, Shoreham Airport, Shoreham Harbour, Old Shoreham Road, and Ropetackle.
- 071FWC2901 - coastal areas of Lancing, including Broadway and Willowbrook caravan park, and Lancing Business Park.
- 071FWC2801 - coastal areas of East Worthing, including Brooklands Pleasure Park, and Harrison Road trading estates.

4.4 Surface water flood risk

The Adur and Worthing area is subject to surface water flooding originating from run-off from the steep slopes of the South Downs. In some instances this type of flooding will be a

combination of seasonal spring flow and field runoff, however the latter can occur in isolation and is often associated with changes to the way that the land is farmed.

The historic surface water flooding records generally correspond with the identified flood risk regions, with a greater number of surface water flooding records in the River Adur Valley, north Lancing, north west of Shoreham-by-Sea, and throughout Worthing.

Several studies have documented that increased grazing intensity coupled with changing cropping practices have caused a change in soil conditions reducing the amount of infiltration. Rills and gullies formed by the use of heavy farm machinery provide conduits for surface water, enabling water to easily run off often moving large volumes of soil in the process. This is termed 'muddy flooding' and has occurred in Lancing, Sompting, Findon and other local areas along the base of the South Downs outside the study area.

Sompting and Findon in particular have long history of surface water flooding. Whilst Findon is outside the study area the Findon Valley area has the potential to be affected by flooding flowing into the study area across the boundary. There were also numerous reports of surface water flooding in Worthing, Lancing, north west Shoreham and Southwick. A number of pluvial events have occurred in Worthing town centre.

An assessment for the potential for surface water flooding in Adur and Worthing has been included in Maps 12 to 14 (Appendix A). This uses Environment Agency surface water datasets including Areas Susceptible to Surface Water Flooding (AStSWF) and Flood Map for Surface Water (FMfSW).

The locally agreed surface water information for Adur and Worthing will be the FMfSW according to the West Sussex PFRA report. The general flow paths are consistent across both the AStSWF and the FMfSW, however they do differ in the spatial extent of flooding and depth of flooding. The extent of flooding shown by the AStSWF is larger than that shown in the FMfSW. This is because the AStSWF was modelled using a longer storm duration and assumed there was no drainage capacity within the sewer network, consequently the flood extent is larger compared to FMfSW. Therefore, the AStSWF should be considered as the 'worse case', with the more realistic FMfSW highlighting those areas where flood risk is more prominent.

There are well-defined flow routes within Adur and Worthing according to the FMfSW. The largest affected areas are north of the A2032 in Worthing. The most obvious flow route follows along the Findon Road southwards to Warren Road. Another flow path runs north to south from the Worthing golf course to the A27 where both flow paths join and spread and pond along the streets in Broadwater. The most affected areas in the north west side of Worthing clearly follow the ditch along Forest Lane. There is also a large ponded area between New Road and Slavington Road in West Durrington. In the south of Worthing, south of A2032, there are many small areas shown to experience ponding.

There are four clear flow routes within Adur which are north of the A27. The most obvious flow route runs north to south from Stamp Bottom passing Lychpole Farm along the Titch Hill Road ponding to the east of Sompting along the Busticle Lane. Another clear flow path follows the Lady Stream east to west from the River Adur Valley. The rest of the flow routes are at the east of the River Adur Valley and run north to south ponding in the area north of the A27.

The area to the south of the A27 is affected by surface water ponding along roads and streets. The significant areas include, immediately south of the Old Shoreham Road in North Lancing, the area between George Parade and A259 in Kingston-by-Sea, the green and the cricket ground in Southwick.

The Lancing Brook Flood Investigation report (2010) also assessed the potential consequences of flooding from surface water sources in the Lancing area. The areas at shown to be at risk in the Lancing Brook study largely agreed with the area identified in the FMfSW. The receptors that were highlighted as having experienced flooding were mainly agricultural and scrub land, local residential roads and the gardens of a small number of residential properties. However, it was highlighted that anticipated changes in climate may increase the risk of localised flooding and may increase the flood risk to Shoreham Dogs Trust and several residential properties. An update to this report stated that the cause of flooding referred to in the report was identified during dredging to be a man made dam immediately

east of the northeast property in Willowbrook Park, which was erected to hold water in the ditches of Willowbrook Park as a water feature and as a consequence raised water levels considerably upstream.

4.5 Groundwater flood risk

Adur and Worthing are positioned at the base of the South Downs and have suffered flooding from groundwater in the past. The geology within the administrative areas of Adur and Worthing is dominated by the chalk of the South Downs, with stripes of clay, silt and sand lying in the centre of the Worthing study area and along the coastline in Adur (Map 2, Appendix A).

A few occurrences of groundwater flooding have been noted during the period of 1960 to 1990 across the study area. Groundwater flooding across West Sussex was recorded during 1974, notably in the River Adur catchment up to and above the chalk band. Significant groundwater flooding was also observed during 1993/94, 2000/01 and 2002/03.

An assessment of groundwater flood risk in Adur and Worthing has been undertaken using the Environment Agency's 'Areas Susceptible to Groundwater Flooding' data. Map 15 (Appendix A) shows how the risk varies across Adur and Worthing. The majority of the Worthing area is susceptible to groundwater flooding. The only area that doesn't appear to be susceptible to groundwater flooding is in the north east of Worthing around the Findon Valley and Worthing Golf course. The central area of Worthing along A2032 is shown to be more susceptible to groundwater flooding with a high-risk category (>=75%); the rest of the area is covered by a range of risk categories (< 25% to <75%).

The majority of Adur District is susceptible to groundwater flooding. The only areas that don't appear to be susceptible to groundwater flooding are the north west and north east parts of the district which are mainly rural. The central area of the district between the A27 and to Shoreham-by-Sea is more susceptible to groundwater flooding with a high-risk category (>=75%); the rest of the area is covered by a range of risk categories (< 25% to <75%).

4.6 Sewer flood risk

Sewer flooding can occur where sewer systems become overloaded with surface runoff. There are two mechanisms of flooding to properties; surcharge flooding, where flood waters back up pipes and enter directly into low-lying properties through toilets and sinks, and surface flooding, where storm sewage exceeds the system capacity, spills from manholes then runs overland and into properties. In Adur and Worthing, storm water is generally drained by the sewer infrastructure; the system is at risk of becoming overloaded in storm conditions. The infrastructure is also at risk of becoming inundated with groundwater when groundwater levels rise.

There have been recorded incidences of sewer flooding in Adur and Worthing. The lack of any significant gradient in the low-lying coastal areas means that sewer networks often rely on pumping to drive flow. Consequently, failure of pumping stations can lead to rapid sewer flooding. The assessment of surface water pumping systems is too detailed for the SFRA, however where relevant, should be investigated further in detailed flood risk assessments.

Records of incidents were obtained from the Environment Agency and Southern Water as part of the SFRA (2008), and were summarised in the 2008 SFRA report, Appendix A. These records have been plotted on Map 3 (Appendix A).

4.7 Flood risk from artificial sources

4.7.1 Reservoirs

There are no reservoirs storing water above ground level in Adur and Worthing. We were not provided with any details of the capacity of Fulbeck Avenue pond (Somerset Lake) although according to the EA, the pond could be large enough to be considered a reservoir (>10,000m^3).

4.7.2 Other water bodies

There are several storage water ponds identified in the SFRA (2008), two of them are located in the Durrington area of Worthing, one is south of the A2032 and the other one is at East Worthing. The two storage ponds appear to be susceptible to both surface water and groundwater flooding. The impact of flooding from these storage ponds has not been assessed due to lack of data.

4.7.3 Canals and other artificial sources

There are no known canals or 'other' potential artificial sources of flooding in Adur and Worthing.

4.7.4 IDB Watercourses

There are several watercourses which are regularly maintained by the Internal Drainage Board including the Pad Stream, Ladywell Stream, Applesham Sewer, Coombes Sewer, Annington Sewer and Shoreham Waterworks Sewer. The IDB also maintains and operates numerous control structures within the District to control water levels.