Hull City Council

Strategic Flood Risk Assessment

December 2016

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Strategic Flood Risk Assessment

SFRA

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1 Executive summary

1.1 Introduction

National Planning Policy and Guidance requires Local Authorities to assess the risk to an area of flooding from all sources now and in the future, through the preparation of a Strategic Flood Risk Assessment (SFRA). Within Hull, the Level 2 Strategic Flood Risk Assessment (2007) has provided guidance to the Local Planning Authority and developers in the assessment of flood risk. This document provides a review and update of the 2007 SFRA to provide guidance in relation to site-specific flood risk issues for individual planning applications and for the Local Planning Authority in progressing site allocations through the Local Plan Process.

This Level 2 SFRA has been prepared in line with the National Planning Policy Framework (NPPF) and accompanying Planning Practice Guidance (PPG). This framework requires a sequential approach, whereby development is steered to areas where flood risk is lowest. These principles are embodied in the Sequential and Exception Tests within Planning Practice Guidance, details of which are provided in Chapter 2 and Chapter 5 of this SFRA.

The SFRA will be reviewed in 2018 to take into account the completion of the Humber Comprehensive review and any new mapping or climate change guidance as a result.

1.2 Local circumstances and the Sequential Test

The vast majority of the city is located within Flood Zone 3. This is the zone where the risk of flooding is highest. Given the limited availability of land in Flood Zones 1 and 2 within Hull, applying a sequential approach purely on the basis of the Flood Zones would have little effect. As a result, the SFRA refines and builds on the understanding of how flood risk varies across the city, taking into account multiple sources of flood risk, sewerage and surface water drainage systems, the presence of flood risk management infrastructure and the complex interactions between these components. This refined information will allow the Sequential and Exception Tests to be applied more effectively. These refined zones, which are shown in Figure 14, should be used when applying the Sequential Test to site allocations in the Local Plan and to any unallocated sites which come forward for development through the planning process.

1.3 Stakeholders in the planning process

The SFRA forms part of the evidence base for the Local Planning Authority in preparing the Local Plan. Paragraph 100 of the National Planning Policy Framework states that local planning authorities should take advice from the Environment Agency and other relevant flood risk management bodies such as Lead Local Flood Authorities (LLFAs), Yorkshire Water and internal drainage boards (IDBs).

Within the context of Hull, the City Council is also the LLFA. LLFAs are responsible for preparing and maintaining a strategy for local flood risk management in their areas. They also have lead responsibility for managing the risk of flooding from surface water, groundwater and ordinary watercourses. On a day to day basis, the LPA must consult the LLFA on all major planning applications in respect of flood risk and drainage matters on the Local Plan and also individual planning applications.

The LLFA works closely with the Environment Agency (EA), which has a national role providing a strategic overview. The EA also has operational responsibility for managing the risk of flooding from main rivers, reservoirs, estuaries and the sea, as well as being a coastal erosion risk management authority. Chapter 3 of the SFRA provides further guidance on how the LPA will consult with the EA and LLFA in relation to development proposals and standing advice which has been developed to respond to local circumstances.

1.4 Place of safety and flood sensitive design measures

The majority of Hull is defended from flood risk through the use of flood alleviation structures, such as engineered walls, embankments, storage lagoons and pumping. The presence of the defences means that the probability of flood risk is low in much of the city but the consequences of a breach or overtop are high. In order to mitigate residual risk and ensure safe access, egress and evacuation (occupants leaving a building unassisted) should flood defences be overwhelmed, it is necessary to consider the requirement for a ‘place of safety’ as an integral part of new developments. Given the low-lying nature of Hull, this will require a place of safety to be effectively integrated into all new developments (including permitted changes of use). A place of safety should be set above the design flood level, this has been produced in Figure 15 which is explained in section 7, and should be able to accommodate all potential occupants of a proposed development. For example a 3 bedroom, 5 person house will need to demonstrate that there is sufficient space for 5 people to wait in the place of safety provided.

All places of safety should, where possible, include an external access point for rescue, depending on the level of flood risk. Further guidance on places of safety is included at Chapter 7 of the SFRA and a checklist is included in section k of the guidance for Local Flood Risk Standing Advice.

In addition to the provision of place of safety, new developments will be required to demonstrate appropriate flood resistance and resilience measures to manage residual risks to property. The SFRA provides guidance on measures to be incorporated into developments to manage these risks (Chapter 6 of the SFRA).

1.5 Flood risk evidence base

In order to provide an auditable and transparent evidence base for the assessment of flood risk, all of the existing flood risk modelling outputs available were collated from Hull City Council (HCC), East Riding of Yorkshire Council, the

Environment Agency and Yorkshire Water, including nationally available datasets. This included outputs from fluvial, tidal, surface water and integrated models that include the sewer system. These models have been verified using the 2007 and 2013 historic flood incidents and outlines.

All the relevant information available was reviewed for data type, coverage, quality, age, detail, resolution, modelling method and limitations, return periods and agreement with equivalent datasets. This included identification of any issues and risks associated with its use. Through this analysis, the most appropriate information available was selected and the process was documented to explain why this information has been used to update the SFRA. Some additional flood modelling was commissioned for the Hull City Council SFRA to fill gaps in the evidence base.

A suite of maps showing flood risk is included in this SFRA, including figures for use in applying the Sequential and Exception Tests. The Sequential Test figure shows the Flood Zones with Flood Zone 3a split into 4 sub-zones. A set of criteria was agreed to define these sub-zones, which was based on design flood depths.

2 National Policy and Hull Principles

The NPPF highlights that planning plays a key role in minimising vulnerability and providing resilience to the impacts of climate change and local planning authorities should adopt proactive strategies to mitigate and adapt to climate change, taking full account of flood risk. Planning Practice Guidance (PPG) accompanies the NPPF and provides detailed guidance on taking flood risk into account in the planning system.

Both NPPF and the accompanying PPG require a sequential approach, whereby development should be steered towards areas where flood risk is lowest. This approach is achieved through application of a Sequential Test. Certain types of development should only be located in areas where there is a heightened risk of flooding in exceptional circumstances. An Exception Test in PPG prescribes these circumstances. This test requires it to be demonstrated that the development would have wider sustainability benefits to the community that outweigh flood risk considerations and also that the development would be safe from flooding over its lifetime. It would not increase the risk of flooding elsewhere, and would reduce flood risk overall where possible. This would not be limited to measures within the development to reduce flood risk, a wider consideration of the strategic approach to flood risk in the area should be considered. This may include contributing towards a flood defence or surface water scheme which offers wider benefits. These approaches should be used for the allocation of sites in the Local Plan. They should also be used in determining planning applications, on unallocated sites.

There are three zones of flood risk used for planning purposes. The risk of flooding is highest in Flood Zone 3. Application of the Sequential Test should guide new development away from Flood Zone 3, wherever this is possible. However, since the vast majority of Hull is within the Environment Agency's Flood Zone 3, there is limited scope to apply the Sequential Test as prescribed by National Policy. The 2007 Strategic Flood Risk Assessment for Hull was therefore tasked with establishing zones of relative hazard within the city to allow application of the Sequential Test in a way that recognises the variation in the nature of the flood hazard across the city. This Strategic Flood Risk Assessment has reviewed the boundaries of these zones of relative flood risk, in light of the best available modelling information from all the Risk Management Authorities information and modelling techniques. The advice for each zone has also been updated. The principle of using this approach remains the most appropriate for Hull, and has the support of relevant stakeholders.

It is noted that PPG advises: *More than one local planning authority may jointly review development options over a wider area where this could potentially broaden the scope for opportunities to reduce flood risk and put the most vulnerable development in lower flood risk areas*[1]. It is accepted that Hull, as the major settlement in the sub-region, should be the focus for development. It would

[1] Reference ID: 7-020-20140306

be contrary to wider policy in the Hull and ERYC Joint Planning Statement to seek to locate development outside of the city to more rural areas. There are significant flood defences in place to protect Hull, and given the extent of housing and industry present, it is intended that these defences be maintained and upgraded as necessary into the future.

2.1 Vulnerability classifications

The PPG definitions of the relative vulnerability of different types of development are shown in Table 1 below. No local changes to these definitions are proposed but it is advisable to also check the Planning Practice Guidance on-line for any updates:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6000/2115548.pdf

Table 1: Land use vulnerability classifications in PPG[2]

Vulnerability classifications:
Essential Infrastructure • Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood. • Wind turbines.
Highly Vulnerable • Police and ambulance stations; fire stations and command centres; telecommunications installations required to be operational during flooding. • Emergency dispersal points. • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent residential use. • Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure').
More Vulnerable • Hospitals

[2] Reference ID: 7-067-20140306

- Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. - Buildings used for dwelling houses, student halls of residence, drinking establishments, nightclubs and hotels. - Non–residential uses for health services, nurseries and educational establishments. - Landfill* and sites used for waste management facilities for hazardous waste. - Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.
Less Vulnerable - Police, ambulance and fire stations which are not required to be operational during flooding. - Buildings used for shops; financial, professional and other services; restaurants, cafes and hot food takeaways; offices; general industry, storage and distribution; non-residential institutions not included in the 'More Vulnerable' class; and assembly and leisure. - Land and buildings used for agriculture and forestry. - Waste treatment (except landfill* and hazardous waste facilities). - Minerals working and processing (except for sand and gravel working). - Water treatment works which do not need to remain operational during times of flood. - Sewage treatment works, if adequate measures to control pollution and manage sewage during flooding events are in place.
Water-Compatible Development - Flood control infrastructure. - Water transmission infrastructure and pumping stations. - Sewage transmission infrastructure and pumping stations. - Sand and gravel working. - Docks, marinas and wharves. - Navigation facilities. - Ministry of Defence defence installations. - Ship building, repairing and dismantling, dockside fish processing and refrigeration 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 such as changing rooms. - Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

2.2 Flood risk vulnerability and flood zone compatibility

The PPG highlights flood risk vulnerability and flood zone 'compatibility' as shown in Table 2 below. Whilst the principles in this table are valid for Hull, to ensure an efficient balanced approach acknowledging the unique situation in Hull this table is complimented by the locally-defined standing advice, which reflects sub-division of Flood Zone 3 into zones of varying flood risk as outlined in Section 2.4 below.

Table 2: Flood risk vulnerability classifications, indicating when the Exception Test is required[3]

http://planningguidance.communities.gov.uk/blog/guidance/flood-risk-and-coastal-change/flood-zone-and-flood-risk-tables/table-3-flood-risk-vulnerability-and-flood-zone-compatibility/

Flood Zones	**Flood Risk Vulnerability Classification**				
	Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	Exception Test required	✓	✓	✓
Zone 3a †	Exception Test required †	✗	Exception Test required	✓	✓
Zone 3b *	Exception Test required *	✗	✗	✗	✓*

Key:

✓ Development is appropriate

✗ Development should not be permitted.

† In Flood Zone 3a essential infrastructure should be designed and constructed to remain operational and safe in times of flood.

* In Flood Zone 3b (functional floodplain) essential infrastructure that has to be there and has passed the Exception Test, and water-compatible uses, should be designed and constructed to:

- remain operational and safe for users in times of flood;
- result in no net loss of floodplain storage;
- not impede water flows and not increase flood risk elsewhere.

2.3 Sequential Test

The NPPF requires that a sequential approach is followed to steer new development to areas with the lowest probability of flooding. Firstly, the PPG [4]states that if development can be allocated in Flood Zone 1, then the Sequential

[3] Reference ID: 7-066-20140306
[4] Reference ID: 7-019-20140306

Test is passed. If development cannot be allocated in Flood Zone 1, the PPG states that development can potentially be allocated in Flood Zone 2 or 3, but may require the Exception Test to be passed, subject to the ‘vulnerability’ of the development in question (as indicated in Table 2 above).

Given the limited availability of land in Flood Zones 1 and 2 in Hull, the SFRA has produced more refined maps which consider fluvial and tidal risk, other sources of flooding, sewerage and surface water systems, flood risk management infrastructure and the interaction between these different components to enable the Sequential Test and Exception Test to be applied meaningfully. The 2007 Strategic Flood Risk Assessment, (SFRA) divided the city into zones 3a (i) (low hazard), 3a (ii) (medium hazard) and 3a (iii) (high hazard). It also set out standing advice for new development in terms of the evidence required to support a planning application and when the Environment Agency should be consulted.

This principle remains valid, and has been updated to take account of new data and modelling, although 4 zones have been used for this updated SFRA, based on flood depth. These zones should be used when applying the sequential test to the site allocations in the Local Plan and to any unallocated sites which come forward for development.

All development within the flood hazard zones plus any areas of Environment Agency Flood Zone 2 or 3 lying outside these hazard areas will need a Flood Risk Assessment (including a site topographical survey) of some sort. As set out in the Local Flood Risk Standing Advice Matrix, in some instances a detailed, site-specific Flood Risk Assessment will be needed. In others, a simpler Flood Risk Assessment incorporating standardised mitigation measures will be sufficient. In cases where, for whatever reason, it is not possible for a development to incorporate the standard mitigation measures, a detailed site-specific FRA will be needed to assess the risks and propose and justify alternative mitigation measures. Figure 13 Exception Test Information highlights the relevant zones or flood depth bands which should be used with the Standing Advice. The zones/depths and the guidance on approaches to managing flood risk within them apply, as follows:

- **Flood Zone 2 (blue on map)-** any Flood Zone 2 as defined by the Environment Agency maps which is not included in the depth information. Refer to column D in the Local Flood Risk Standing Advice.

- **Flood Depth less than 300mm and remainder of Flood Zone 3 (light yellow and green on map)** includes the remainder of FZ3a not within the other sub-zones described below – detailed advice is included in the Standing Advice Matrix, column C.

- **Flood Depth 300-600mm (darker yellow)** includes areas within FZ3a with predicted flooding between 0.3 and 0.6m depth - detailed advice is included in the Standing Advice Matrix, column B.

- **Flood Depths 600m + (orange, red and purple on the map)** includes areas within FZ3a with predicted flooding greater than 0.6m depth - detailed advice is included in the Standing Advice Matrix, column A.

- **Flood Zone 3b** (hashed on map) retains the overall designation as ‘functional floodplain’ and therefore should not be allocated or permitted for anything other than water-compatible developments or essential infrastructure that has to be there and has passed the Exception Test. Consultation with the Environment Agency will be required in all cases. The definition of functional floodplain remains the same as the 2007 SFRA; land where water has to flow or be stored in times of flood for fluvial or tidal flood incidents with an annual probability of 5% or greater. Due to the fact that Hull is defended the functional floodplain is mapped around watercourses where defences in present day are not in place or at a low standard of protection.

2.4 Exception Test

The PPG[5] requires the Exception Test to be undertaken following successful application of the Sequential Test (Further detail on the Sequential Test is provided in Section 5). Generally, the Exception Test is required when

- 'highly vulnerable' development is allocated in Flood Zone 2;
- 'more vulnerable' development is allocated in Flood Zone 3a; and
- 'Essential infrastructure' is proposed in Flood Zone 3a or 3b.

This is illustrated in Table 3 in Section 3.

Part one of the Exception Test requires development to provide wider sustainability benefits to the community that outweigh flood risk. Part two of the Exception Test requires provision of evidence that a development will be safe from flooding for its lifetime, without increasing flood risk elsewhere and, where possible, will reduce flood risk overall. This is described in more detail below.

Part 1: Evidence of wider sustainability benefits

Following application of the Sequential Test, some developments will also need to be subject to the Exception Test. The sustainability objectives in the Local Plan's Sustainability Appraisal should form the starting point for assessing whether the development may deliver wider sustainability benefits to the community. Any benefits must then be weighed against the negatives of locating development in a flood risk area. This would be informed by the conclusion of a Flood Risk Assessment. Planning conditions or obligations can help to ensure that any wider sustainability benefits are actually delivered.

Part 2: Ensuring development is safe for its lifetime

Part two of the Exception Test requires that the allocated development will be 'safe for its lifetime'. Firstly, provision of appropriate flood warning and evacuation procedures need to be considered in the design, layout and operational procedures associated with planned developments. The PPG requires that a Level 2 Strategic Flood Risk Assessment should also inform the second part of the

[5] Reference ID: 7-023-20140306

Exception Test for allocations[6]. This is the purpose of this document, as it assesses the flood risk in much greater detail and provides the evidence required to apply a sequential approach. Part Two of the Exception Test ensures that development is safe from flood hazards for the lifetime of the development, taking climate change into consideration.

Part 2a: Safety of a development

The PPG provides guidance on ensuring the safety of development[7]. Built measures can be integrated into development to make it safe from flooding by:

- providing adequate flood risk management infrastructure to control flood risk to acceptable levels, which will be maintained over the development's lifetime, this could include contributions to flood defence schemes which not only protect the development site but a wider area;
- designing buildings to avoid flooding (for example, raising floor levels, using flood resistance measures to keep the water out);
- designing buildings to minimise the amount of damage that would occur should water enter a property (for example garages only on the ground floor, raising electrical points); and
- Provision of appropriate flood warnings, a place of safety and procedures for access and egress by the emergency services.

These measures require assessment and agreement on a suitable design flood level, using the information in the SFRA and any local evidence which takes into account future climate change impacts and uncertainties. A safety margin above this flood level should also be provided to allow for uncertainties.

In addition, the PPG requires specific local circumstances to be taken into account, including:

- the characteristics of a possible flood (for example, the type and source of flooding and frequency, depth, velocity and speed of onset) – Figures 7 and 8 provide useful information on modelled velocities and flood hazard following a breach of Hull's fluvial and tidal defences);
- the safety of people within a building if it floods and also the safety of people around a building and in adjacent areas;
- access and egress for the emergency services;
- the structural safety of buildings; and
- The impact of flood on the essential services provided to a development.

These built measures can be supplemented by emergency evacuation plans and use of Environment Agency Flood Warning systems to reduce safety risks associated with flooding.

[6] Reference ID: 7-025-20140306
[7] Reference ID: 7-054-20150415

Part 2b: Lifetime of a development

The lifetime of a residential development should be considered to be 100 years, unless there is a specific justification for a shorter amount of time. The capital and revenue investment which is allocated and programmed for the flood defences in Hull justifies using a 100 year period for the lifetime of development. For non-residential development, the length of a lifetime is dependent on the characteristics of the development. In Hull, 75 years is currently used as the lifetime for non-residential development.

The PPG[8] recommends that planners use their experience within their locality to assess how long they anticipate the development being present for. If developers wish to adopt a different timescale for the lifetime of their development, they would be expected to justify why as part of their Site-Specific Flood Risk Assessment.

The relevant climate change allowances need to be considered in relation to the lifetime of the development. The climate change allowances used for the SFRA are incorporated into the various Risk Management Authorities existing hydraulic models and data. Two climate change scenarios were assessed:

1. Figure 3 shows sea level rise plus a 20-30% increase in river flows, which is consistent with the central and higher central allowances for river flow in the climate change allowances guidance.
2. Figure 3b shows sea level rise plus a 50% increase in river flows (for available hydraulic models), which is consistent with the upper end fluvial flow allowances. Developers are advised to consider these allowances for the assessment of flood risk for major or highly vulnerable developments.

The Environment Agency provides guidance on climate change allowances for use in flood risk assessment and design, updated in April 2016: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

[8] Reference ID: 7-026-20140306

2.5 Standing Advice Matrix

The standing advice matrix sets out when a bespoke, site specific Flood Risk Assessment will be required and when the Environment Agency must be consulted by the council. It provides advice on activities that should ensure that a development will be provided with an appropriate level of flood mitigation. This matrix performs the same role as the PPG 'vulnerability and flood zone compatibility' in Table 2, but is specific to the unique circumstances in Hull. It includes recommendations from the Level 2 SFRA about how to make a development safe for its lifetime that may be appropriate for certain types of smaller and less vulnerable developments in less hazardous zones. It also shows when a Drainage Impact Assessment is required and when to consult the Lead Local Flood Authority on surface water (see brief description below and section 8 for more information).

The standing advice matrix has been developed so it performs, amongst other things, the same role as the PPG 'vulnerability and flood zone compatibility' but is specific to the unique position of Hull. The standing advice matrix for Hull is on the Hull City Council website along with the guidance on how to use it.

2.6 Drainage Impact Assessments (DIA)

These are standalone reports which are provided by the developer or applicant and which identify any drainage issues which may arise from a development. They also identify suitable means of storing and discharging surface water from the proposal without increasing surface water or flood risk elsewhere. The drainage infrastructure of proposed developments should seek to reduce the overall level of flood risk both in the area of the application and beyond.

Drainage and flood risk are material considerations in the determination of planning applications. A satisfactory means of surface water disposal must be demonstrated in order to show that:

a) the site can be appropriately developed;

b) any land-take required for proposed drainage infrastructure has been allowed for; and,

c) due consideration has been given to the impact of the proposed development on the drainage catchment area.

Please find the full guidance for Drainage Impact Assessments: http://www.hullcc.gov.uk/portal/page?_pageid=221,1429916&_dad=portal&_schema=PORTAL

3 Flood maps

3.1 Introduction

A suite of flood map figures is included in this SFRA. These are listed and described in Section 4.2. These should be used in conjunction with this report to:

1. determine the variations in risk from all sources of flooding across the Council area;
2. inform the sustainability appraisal of the Local Plan, so that flood risk is fully taken into account when considering allocation options and in the preparation of plan policies;
3. apply the Sequential Test and, where necessary, the Exception Test when determining land use allocations and planning applications (Figure 13 and Figure 14);
4. identify the requirements for site-specific flood risk assessments in particular locations, including those at risk from sources other than river and sea flooding;
5. determine the acceptability of flood risk in relation to emergency planning capability; and
6. consider opportunities to reduce flood risk to existing communities and developments through better management of surface water, provision for conveyance and of storage areas for flood water.

The data sources and associated criteria used in these figures are described in Appendix B.

3.2 List of maps and description

Table 4: List of figures

Fig	Title	Description
0	Ground levels	Ground levels from LiDAR (Light Detection and Ranging) Digital Terrain Model data.
1	Standard of Protection	Standard of Protection of River Hull and Humber defences without freeboard allowance.
2	Flood depths with defences	Maximum flood depths for fluvial and tidal flood sources assuming existing flood defences are present and do not fail. Flood depths based on 1% fluvial event and 0.5% tidal event.
3	Flood depths with defences with climate change	Maximum flood depths for fluvial and tidal flood sources assuming existing flood defences are present and do not fail. Flood depths based on 1% fluvial event and 0.5% tidal event with allowance for climate change indicative of 2080s to 2110s. In this figure, the central / higher central allowance for increase in river flow is used.
3b	Flood depths with defences with climate change based on upper end fluvial flow increase	Maximum flood depths for fluvial and tidal flood sources assuming existing flood defences are present and do not fail. Flood depths based on 1% fluvial event and 0.5% tidal event with allowance for climate change indicative of 2080s to 2110s. In this figure, the upper end allowance for increase in river flow is used.
4	Hull SFRA Flood Zone 3 with and without defences	Maximum flood extents for fluvial and tidal flood sources with and without defences. Flood extents based on 1% fluvial event and 0.5% tidal event.
5	Areas benefitting from Hull Tidal Surge Barrier in a 0.5% event	The areas benefitting from the Hull Tidal Surge Barrier in a 0.5% flood event.
6	Flood depths for modelled breaches	Maximum flood depths for modelled breaches of the River Hull (fluvial) and Humber frontage (tidal) based on a 1% fluvial event and 0.5% (or closest equivalent) tidal event.
6b	Flood depths for modelled breaches with climate change	Maximum flood depths for modelled breaches of the River Hull (fluvial) and Humber frontage (tidal) based on a 1% fluvial event and a 0.5% tidal event with allowance for climate change to 2116. Defence levels are assumed sufficient to prevent overtopping for the purposes of this figure. Flood depths are for modelled breaches only, flooding from overtopping of defences is not include in this figure.
7	Flood velocity for modelled breaches	Maximum velocity for modelled breaches of the River Hull (fluvial) and Humber frontage (tidal) based on a 1% fluvial event and a 0.5% (or nearest equivalent) tidal event for present day climate.
8	Flood hazard for modelled breaches	Maximum flood hazard for modelled breaches of the River Hull (fluvial) and Humber frontage (tidal) based on a 1% fluvial event and a 0.5% (or nearest equivalent) tidal event for present day climate.
9	Surface water flood depth 3.3% event	Maximum surface water flood depths for a 3.3% event.
10	Surface water flood depth 1% event	Maximum surface water flood depths for a 1% event.

Fig	Title	Description
11	Surface water flood depth 0.1% event	Maximum surface water flood depths for a 0.1% event.
12	NOT USED	
13	Exception Test figure	This map is for use in applying the Exception Test. It shows maximum flood depths from the sources listed below, the remaining areas of Flood Zones 2 and 3a and Flood Zone 3b and the main river 20m buffer strip. 1) Overtopping with current defence levels for 1% fluvial event and 0.5% tidal event for present day climate. 2) Overtopping with current defence levels for 1% fluvial event with allowance for climate change to 2116. The upper end fluvial flow increase (50% increase) scenario is used where available. Note there is no significant overtopping of the River Hull in Hull City Council. 3) Breaching of defences for 1% fluvial event and 0.5% tidal event with allowance for climate change to 2116. This is based on the assumption that the Humber defences are raised to mitigate sea level rise so that there is no overtopping. Note flood depths from River Hull breaches are insensitive to climate change. 4) Surface water for 0.1% rainfall event for present day climate.
14	Flood Zones for Sequential Test	This map is for use in applying the Sequential Test and shows Flood Zones 1, 2, 3a and 3b based on fluvial, tidal and surface water flood sources. Flood Zone 3a split into 4 sub zones; the split is based on flood depths for present day climate, assuming current defence levels, from the following flood sources: • Overtopping of defences (1% fluvial, 0.5% tidal) • Breaching of defences (1% fluvial, 0.5% tidal) • Surface water (1% event) Flood depth bands used are: • FZ 3a i (low): No flooding in the design event for the flood sources in note (2) above but still within FZ 3a • FZ 3a ii (medium-1): 0.0 – 0.3m • FZ 3a ii (medium-2): 0.3 – 0.6m • FZ 3a ii (high): > 0.6m
15	Floor levels for 'places of safety'	Map showing floor levels required for 'places of safety' excluding supplementary requirements for surface water flood risk. Floor levels are based on the maximum water level for the defended situation and the repaired breach situation for the 0.1% event (or the most extreme available) including allowance for climate change representative of the year 2115.

4 Planning recommendations

This section of the SFRA sets out guidance on the application of the Sequential and Exception Tests within the defined City Centre as the principal locations for the concentration of new development. This section also provides guidance for individual planning applications on unallocated sites and also in relation to the requirements for drainage statements in support of major applications.

The guidance as set out within this chapter should be read in tandem with the National Planning Policy Framework, Planning Practice Guidance and Non-statutory technical standards for sustainable drainage systems. Flood Risk Assessments should also be prepared having regard to the contents of this SFRA and should adequately demonstrate compliance with the measures set out in the standing advice matrix, depending on the vulnerability classification of the development.

4.1 General principles in city centre

- The role of the City Centre in terms of service provision, jobs, retail, leisure and housing is accepted as having a strategic role in the future development of the sub-region. This means that applications for development within the City Centre should be sited on the most appropriate site within the City Centre, and should not be required to consider sites outside of the city centre. The following principles apply: Within the City Centre such justification could include the consideration of the wider function of the City Centre as the primary area for retail, leisure and economic development or consideration of inclusive access for non-residential uses;
- The provision of access/egress points and a place of safety above the flood level specified in this SFRA (Figure 15);
- Flood resistance and resilience measures should be incorporated in the overall design of any development, particularly for mixed use and multi storey development types.
- Less vulnerable uses should be sited on lower ground floors with more vulnerable above.

4.2 Prior approval applications in city centre

In respect of proposals which are for prior approval under changes to the Town and Country Planning (General Permitted Development) (England) Order 2015 (A1/A2 to C3, specified sui generis uses to C3, and B1a/B8 to C3 and C4 (HIMO-Houses in Multiple Occupation); these should be accompanied by an assessment of the flood risks at the site, the incorporation of appropriate flood resistance and resilience measures and ensuring that a place of safety is provided. This should be demonstrated within a flood risk assessment submitted with the application. Where a place of safety cannot be provided (for instance through the change of use from retail to residential at ground floor level only) the LPA should consider whether appropriate alternative emergency planning measures or sufficient flood resistance/resilience measures have been incorporated into the proposals (dependent on the level of flood risk within the area).

4.3 Unallocated/ windfall sites

Due to the limited amount of land outside Flood Zone 3 it is appropriate to steer less vulnerable development to the Low Hazard location to safeguard the small quantities of land in Flood Zone 1 and 2 for More Vulnerable and Highly Vulnerable development types.

The area of search for a Sequential Test should normally be city wide. However, where the proposal is for development of one or two dwellings, which would fall within Use Class C3(a), the area of search should be the ward in which the application site is located. This is to reflect the fact that there are some areas of the city where there are very few opportunities to develop housing except on smaller sites where the addition of one or two dwellings would not have a material impact on the number of dwellings in the wider area. It is also based on the fact that in order to meet the housing requirement of 760 houses per annum, a target of 50 windfall sites is required. If these are not spread evenly across the city it could result in sterilisation of some wards and undue burdens on infrastructure and amenities in others. This is based on schools, services and general health provision.

It may be that there are some developments which are designed to serve a particular catchment. Where this is the case, appropriate regard will have to be had to the applicant's case.

4.4 Drainage Impact Assessments

Hull City Council has prepared a Sustainable drainage system (SuDs) design guide. This document sets out local requirements for SuDS and also provides guidance on planning, design and delivery of SuDS. HCC have also prepared a Guide to Drainage Impact Strategies and Drainage Impact Assessments (December 2015). Drainage Impact Assessments should be prepared to accompany all major applications and be prepared in line with the guidance set out within these documents.

5 Managing residual risks through local property protection

5.1 Introduction

New development should not result in the creation of new flood hazards to either new or existing development. Where new developments are built in areas that benefit from existing flood defences, a risk remains that these defences may fail or be overtopped. This is known as a residual risk. The PPG states that enhanced local property protection measures may need to be incorporated into the design of buildings and other assets that fall into this category. This is to minimise the impacts should the defences fail or be overtopped.

These measures should not be used to justify the safety of a development. Preference should always be given to avoiding flood risks by locating developments in areas of low risk. The Sequential and Exception Tests (see section 4) should be applied first to assess the appropriateness of development.

Preventing inappropriate development and keeping people out of the high risk areas is a priority over resistance and resilience measures. Local property protection measures fall into two categories: resistance measures and resilience measures. Flood resistance, or dry proofing, stops water from entering a building whereas flood resilience, or wet-proofing, accepts that water will enter the building, but through careful design will minimise damage and allow re-occupancy of the building quickly. These two techniques are described in more detail below. Further more detailed information can be found in the 'Flood Resilient Development' report by Yorkshire Futures.

http://www.jbaconsulting.com/sites/default/files/documents/Flood%20Resilient%20Development%20Doc.pdf

5.2 Flood resistance

The PPG states that flood resistant construction can prevent entry of water or minimise the amount of water that may enter a building where there is short duration flooding with water depths of 0.6 metres or less. The PPG states that this form of construction should be used with caution and also be accompanied by resilience measures. The DCLG document 'improving flood performance of new buildings', as with flood resilience, provides guidance relating to flood resistance. The document defines flood resistance as 'measures taken at building level to prevent floodwater entering the building and damaging its fabric.' The document provides guidance on the measures that can be adopted for resistance, on site and at building level, and these include low-permeability materials, flood resistance products (such as door flood guards) and other design considerations (such as layout of internal space and house fittings).

5.3 Flood resilience

The PPG[9] states that flood resilient buildings are those designed and constructed to reduce the impact of flood water entering a building so that no permanent damage is caused, structural integrity is maintained and drying and cleaning becomes easier, thereby allowing for quicker re-occupation. The PPG refers to a document by the Department of Communities and Local Government (DCLG) called 'improving the flood performance of new buildings: flood resilient construction'.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7730/flood_performance.pdf

The document defines resilience as 'sustainable measures that can be incorporated into the building fabric, fixtures and fittings to reduce the impact of floodwater on the property.' The document provides guidance on how to improve the resilience of new properties in low or residual flood risk areas by the use of suitable materials and construction details. Guidance is provided on: building materials, foundations, floors, walls, doors and windows, fittings and services.

5.4 Local Policy: Hull SFRA

The Hull City Council Strategic Flood Risk Assessment (SFRA) is a tool that can be used to assess all types of flood risk and provides recommendations for the best and most appropriate use of resistance and resilience interventions. Hull-specific recommendations on flood risk management measures should be implemented into design within Flood Zone 2 and 3 areas. These include:

- Resistance through raising floor levels above the average ground level or adjacent road level whichever is higher. The information should be provided in topographical survey information which should all be in mAOD.
- Other flood resistance measures including:
    - Flood gates to doors;
    - Air brick covers;
    - Floating house type construction
- Resilience through:
    - Avoiding ground floor sleeping accommodation in multi-storey buildings;
    - Use of ground floor levels for storage and/or utility areas;
    - Provision of concrete floor slabs at ground floor level;
    - Damp proof membranes;
    - Electrical circuits lowered from the ceiling; raised sockets;
    - Horizontal plaster boards;

[9] Reference ID: 7-059-20140306

    - Resilient flooring, such as tiles
- Inclusion of surface water attenuation schemes and provision of grey water recycling schemes features and rain water harvesting (e.g. water butts and SuDS), to reduce loading on the local surface water drainage network.
- In some cases site specific flood risk assessments may justify or identify measures above and beyond standing advice measures.
- Consent for the use of basements in new developments for habitable uses in high, medium and low hazard is not permitted. Consent for change of use for basements in low hazard would be permitted if basement access points are situated 300mm above average ground level or adjacent road level whichever is higher.
- Developers should always consider flood flows and areas where flood water would pond in flood incidents. Development should be designed accordingly with the use of storage areas provided if appropriate.

6 Place of Safety

PPG provides guidance in relation to ensuring development can be made safe from flood risk[10]. This guidance is clear that in considering safety, specific local circumstances need to be taken into account, including:

- the characteristics of the type of flooding likely to affect a site , e.g. the type and source of flooding and frequency, depth, velocity, speed of onset and duration;
- the safety of people within a building if it floods, and also the safety of people around a building in adjacent areas, including people who are less mobile or who have a physical impairment. This includes the ability of residents, users and the emergency services to safely access and exit a building during a design flood[11] and to evacuate before an extreme flood;
- the structural safety of buildings; and
- the impact of a flood on the essential services or utilities (gas, water, sewerage, electricity, telecommunications) provided to a development.

Paragraph 040 of the PPG[12] outlines the requirements to ensure safe evacuation and flood response procedures are in place for new developments in flood zones. In locations where there is a residual risk of flooding due to the presence of raised flood defences, judgements on whether a proposal can be regarded as safe will need to consider the feasibility of evacuation from the area should it be flooded.

Given that the vast majority of the city lies within an area which could be affected in a flood, predominantly from a beach or overtopping of existing defences, flooding could happen quickly and with no or little warning. The feasibility of safe evacuation prior to the onset of flooding may be limited. As such it will be a city wide requirement (not including Flood Zone 1) to integrate a place of safety into all new developments (including permitted changes of use to more vulnerable uses). For residential developments in particular, a place of safety should be set in accordance with Figure 15. This figure is based on the design water level for the defended situation and the 'repaired breach' situation for the 0.1% event (or the most extreme available) including climate change representative of the year 2115.

The place of safety should be able to accommodate all potential occupants. For example a 3 bedroom, 5 person house will need to demonstrate that there is sufficient space for 5 people to wait in the place of safety for the likely duration of the flooding

Where possible the place of safety should include an external access point for evacuation, however this will be dependent on the level of flood risk.

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[10] Reference ID: 7-054-20150415
[11] The design flood is the flood which the resilience and resistance measures have been designed for. This is typically the event with an annual exceedance probability of 1% (1 in 100) or 0.5% (1 in 200) with an allowance for climate change over the lifetime of the development factored in.
[12] Reference ID: 7-040-20140306

Developers will need to demonstrate sufficient space within the Place of Safety for expected occupancy levels as part of the application documents. Developers shall also set out an Evacuation Plan with procedures for ensuring future residents are aware of the specific measures and early warning systems and should refer to Figure 7 for velocity of flooding. The evacuation plan will also identify whether an external access point will be necessary based on the level of flood risk applicable to the site.

A developer's flood emergency/evacuation plan self-assessment checklist tool prepared with the Emergency Planners and a Place of Safety Checklist is included on the Hull City Council Flood Risk website.

7 Sustainable Drainage Systems

Sustainable Drainage Systems (SuDS) manage surface water run-off at source and allow for slower discharge of rainwater to receiving watercourses. SuDS approval is the responsibility of Local Planning Authorities, who must consult the Lead Local Flood Authority. Hull City Council performs both functions in the City of Hull. The non-statutory technical standards for sustainable drainage systems (Defra, 2015) set out the nominal requirements for the sustainable drainage of new developments.

Paragraph 079 of the PPG[13] sets out that new development should only be considered appropriate in areas at risk of flooding if priority has been given to the use of SuDS. For major applications (10+ dwellings, +1,000m^2 or 1 hectares http://www.legislation.gov.uk/uksi/2015/595/pdfs/uksi_20150595_en.pdf) SuDS should be provided unless demonstrated to be economically and technically unviable. Applications should therefore demonstrate the appropriateness of SuDS having regard to the hierarchy of drainage options as set out within PPG[14] . Major applications will need to therefore demonstrate and provide the following information:

- Outline design demonstrating compliance with relevant national standards, including evidence of the inappropriateness of SuDs if non-SuDS systems are proposed;
- Existing and proposed run-off rates from the site, including an appropriate allowance for climate change;
- Outline surface water drainage design, including an appraisal against the hierarchy of run-off destinations;
- Proposals for whole-life maintenance of any SuDS system, including where appropriate evidence of agreement with SuDS maintenance providers.

[13] Reference ID: 7-079-20150415

[14] Reference ID: 7-080-20150323

7.1 Engagement and Expert Advice

HCC planners will need to consult their LLFA staff, any sewerage undertaker, the Environment Agency, the relevant highways authority, and the relevant internal drainage board as appropriate dependent on the SuDS proposals being prepared by the applicant.

7.2 Maintenance

Through the implementation of relevant conditions or legal agreements, HCC should require that the applicant to maintain SuDS to a minimum level of effectiveness or secure the agreement of a third party to maintain these. However, this will require there to be at least one viable option for delivering sustainable maintenance, otherwise a planning condition cannot be attached to permission. Maintenance measures will also need to be affordable for occupants following development. Potential Maintenance Options could be set out as required as follows:

Maintenance Companies	Householders and premises occupiers would pay for sustainable drainage systems maintenance as part of the annual service charge or equivalent. Another potential funding path is a commuted sum paid by the developer to the Maintenance Company, however this is not considered to be an optimal route.
Water and sewerage companies	The developer could build (or contribute towards the construction of) a SUD system that the water company would subsequently own. The system would be included within a Water and Sewerage Company's ordinary charging scheme, and maintenance costs would be funded through the surface water drainage element of household water bills.
Local government	Local authorities could take on maintenance responsibility as part of their wider public open space and amenity management function and/or where the sustainable drainage system provides advantages for the wider community. Where local authorities opt to take on the long term responsibility, Government expectations are for them to use their existing powers to charge for maintenance at cost recovery only.
Private Individuals	Where SUDs are simple, easy to maintain systems, serving only small numbers of properties, the owners of those properties could also agree to maintain the systems collectively. Given the guidance in relation to the application of SuDS being to 'major' applications we would suggest limited potential for this route in HCC. This may be appropriate in areas of Flood Zone 1.

Appendix A – Background

A1 Hydrology, geology and soils

A1.1 Hydrology

The River Hull catchment includes large areas of the Yorkshire Wolds in its Headwaters as well as flat, artificially drained agricultural land in its middle and lower reaches. Holderness Drain catchment includes flat artificially drained agricultural land to the east of the River Hull as well as a large area of slightly higher land to the east of Monk Dyke in Eastern Holderness.

The River Hull is fed by a number of springs and becks within the Yorkshire Wolds, which join together south of Driffield in the East Riding of Yorkshire. The river flows through open countryside before it skirts past the eastern edge of the town of Beverley and reaches Kingston upon Hull. It flows through the centre of the heavily populated and industrial area of the City of Kingston upon Hull, before joining the Humber estuary at Victoria Pier, near to The Deep and the Tidal Surge Barrier.

The upland part of the catchment is made up of highly permeable chalk which means that there is comparatively little surface runoff from these catchments but there is a large baseflow component. This baseflow component varies significantly throughout the year and during large storm events.

The low level drains which drain much of the flat, low lying land adjacent to the middle and lower reaches of the Hull and the Holderness Drain are almost entirely made up of artificial channels. These channels form a complex network where flow direction and sub-catchment boundaries are not clearly defined.

A1.2 Geology and soils

The solid geology beneath Hull comprises Chalk. Within the city this is overlain by a thick layer of tills composed of loam, clays, sands and gravels which are a product of glacial deposition (Figure 1). It is ultimately the soils which play the greatest role in controlling run-off and flood propagation. Soils affect a number of factors relating to the time it takes rainfall to enter river channel. The permeability of a soil affects the amount of rainfall which will infiltrate into the soil rather than run off the surface of it. It also affects the speed at which water will percolate through the soil into the underlying geology. The predominant soil type in the city is seasonally wet deep clay, which typically has a low permeability, which naturally would cause much of the rainfall to run off the surface as opposed to infiltrate into the soil. This has significant implications for the types of SuDS that will be appropriate in Hull, as infiltration measures may well not be effective.

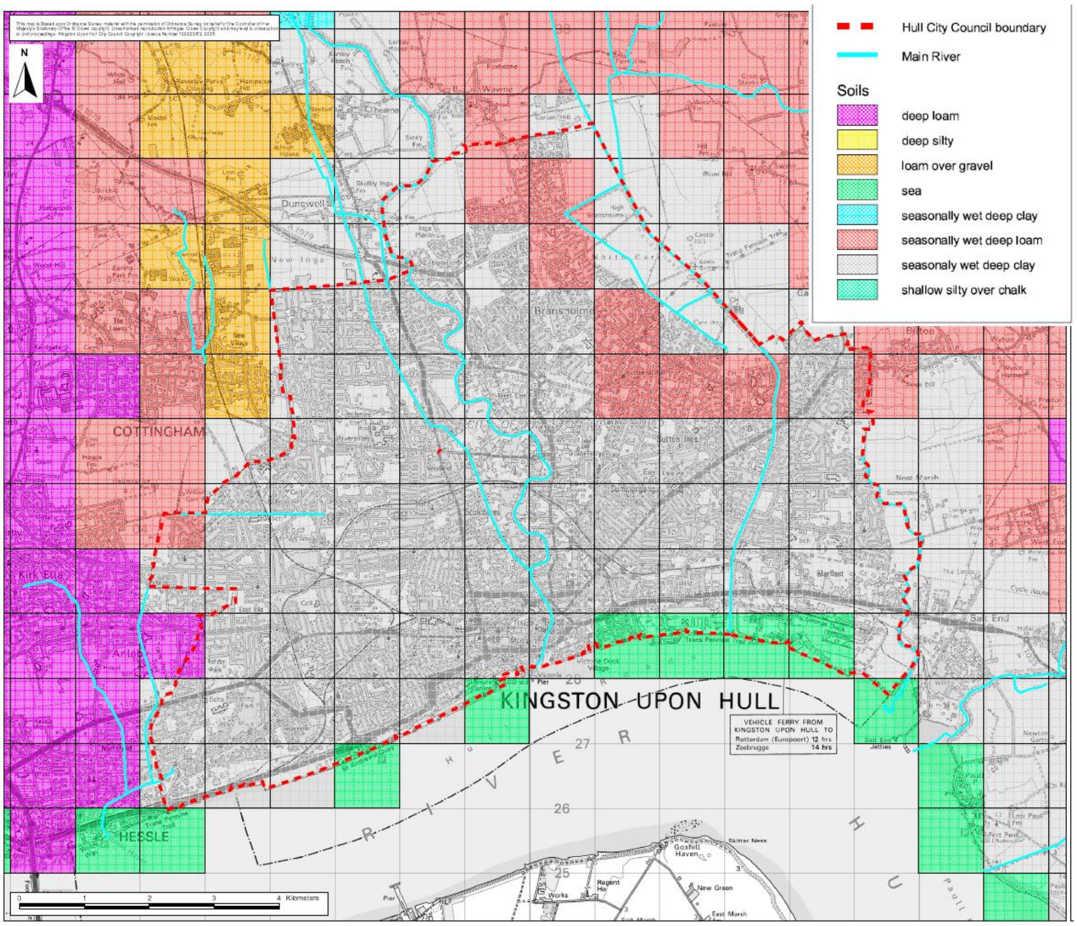


Figure 1: Soil types in Hull

A1.3 Groundwater

Groundwater flooding occurs as a result of water rising up from the underlying rocks or from water flowing from abnormal springs. This tends to occur after much longer periods of sustained high rainfall. Generally groundwater flooding occurs during the winter and spring when groundwater levels reach their peak and start to come above ground in low lying areas. Groundwater flooding takes longer to dissipate because groundwater moves much more slowly than surface water and will take time to flow away underground.

Groundwater flooding most commonly occurs in the areas which lie on the edge of the Wolds, to the west of Hull City Council, as these are the locations where the principal aquifers come to the surface. Occasional and sporadic elevated groundwater levels in the Cottingham area have caused flooding in the past, though this is just outside of Hull City Council. The Environment Agency is not aware of any recent examples of groundwater flooding within Hull City Council.

Source Protection Zones (SPZs) show the risk of contamination from any activities that might cause pollution in the area. Flood storage may not be appropriate in SPZ 1 as the contaminated water may cause pollution of the source. Some flood barrier methods may not be successful if groundwater flow is not taken into account.

A2 Flood sources

The main sources of flooding within Hull City Council are fluvial, tidal and surface water; which are discussed further below. Other potential sources of flooding include:

1. **Groundwater:** Whilst there is awareness of a high water table there have been no confirmed flood risk areas in the Council area for this flood source. Consideration must be given to water from the chalk aquifer and water from the superficial deposits.

2. **Sewer flooding:** Locations of known sewer flood risk are given in the original SFRA report (2007). The data sources used in the current SFRA to assess surface water flood risk include representation of the underlying sewer system and so can be considered as representing surface water and sewer flood risk. For simplicity this is referred to as surface water flood risk herein.

3. **Reservoirs:** The only reservoir (greater than 10,000m^3 stored volume) identified in the council area is the Bransholme lagoon operated by Yorkshire Water, which was enlarged in 2010. This lagoon is used to store flood water pumped out of the sewer system during flood conditions before being discharged into the River Hull. The requirement for regular inspections by a Supervising Panel Engineer means that the likelihood of structural failure of reservoirs is considered to be minimal. The risk of failure remains, however, and the Environment Agency has mapped the potential extent of flooding resulting from the failure, though this is believed to be based on the pre-enlarged reservoir. The Environment Agency map shows flooding would occur in the immediate vicinity as well as extending northwards into Kingswood, north eastwards beyond Bude Road and south westwards beyond the western bank of the River Hull. As the probability of failure of this reservoir is considered to be minimal, reservoir flood extents have not been used to define the SFRA flood zones.

A2.1 Fluvial

Fluvial flood risk occurs though one or both of the following mechanisms:

1. Overtopping of defences (or of bank tops where defences are not present): This occurs when the water level in the watercourse exceeds the defence crest (or bank tops where defences are not present), e.g. due to high flows and/or due to high tide levels and/or failure of flood defence asset(s).

2. Breaching of flood defences: This occurs when a flood defence fails if the water level in the watercourse is above the ground level behind the flood defence. Breach flooding only occurs for raised waterbodies with water levels above surrounding ground level, these are the River Hull and the Humber. The probability that a defence breaches is dependent on the type of defence, its structural condition and the water level.

3. Pump failure: where a pumping stations is required to assist with high fluvial flows when tide locking occurs. This situation is the East Hull Pumping Station on Holderness Drain.

The fluvial main river watercourses identified in the council area are:

- Acre Heads Drain / Sand Dyke (adjacent to council boundary)
- Beverley & Barmston Drain
- Cottingham Drain (adjacent to council boundary)
- Fleet Drain
- Foredyke Stream
- Holderness Drain
- River Hull
- Old Fleet Drain
- Setting Dyke
- Suttoncross Drain

A2.2 Tidal / estuarine

Tidal / estuarine flood risk to Hull is from the Humber though one or more of the following mechanisms:

1. **Overtopping of defences** (or ground levels where defences are not present): This occurs when the water level in the Humber exceeds the defence crest (or ground levels where defences are not present) due to very high tidal levels, e.g. during a tidal surge. Overtopping can also occur from waves when the Humber water levels are significantly lower than the defence level (or ground levels where defences are not present).
2. **Breaching of flood defences:** This occurs when a flood defence fails if the water level in the Humber is above the ground level behind the flood defence. Breach flooding only occurs when Humber water levels are above surrounding ground level. The probability that a defence breaches is dependent on the type of defence, its structural condition and the water level.
3. **Propagation up the River Hull**: In the event that the Hull Tidal Surge Barrier (HTSB) fails or is deployed too late, a tidal surge could cause water from the Humber to propagate up the River Hull and overtop the River Hull banks causing flooding. The probability of the HTSB failing is considered low.

A2.3 Surface water

Surface water flooding occurs when surface water runoff from rainfall cannot drain away fast enough. In urban areas this is often due to the intensity of the rain overwhelming the drainage system. Two distinct types of surface water flooding are:

1. Flooding due to the incident rainfall causing local ponding in low lying areas. This is likely to occur through much of Hull due to the flatness of the land. Flood velocities are typically low.
2. Flooding due to overland flow of rainfall runoff originating from higher ground. Overland flow from the land to the west can flow into some parts of western Hull. Flood velocities are higher than for ponding.
3. Failure of pumping stations used to alleviate flood risk and control flood flows.

A3 Flood Defences

The following fluvial and tidal flood defences assets have been identified in the council area:

A3.1 River Hull linear defences

Existing defences on the River Hull consist of steel piling, timber wharfs, concrete walls and masonry walls within the city. The flood defence infrastructure on the River Hull is in a very variable condition; in some parts of the city the hard defences are in a poor condition. It should be noted that defences in poor condition may not necessarily have a low standard of protection (based on probability of overtopping) and vice versa. The standard of protection excluding freeboard allowance is shown in Figure 1. This shows that current standard of protection of the River Hull defences through Hull is greater than 1 in 200 (0.5% annual probability), assuming the Hull Barrier operates as intended. However, there is an isolated low points in the flood defence where the standard of protection is between 1in 75 and 1 in 100 (1.33% and 1% annual probability). .

A3.2 Hull Tidal Surge Barrier

The Hull Tidal Surge Barrier, located at the mouth of the River Hull where it joins the Humber, has been in operation since 1980 to prevent high sea levels caused by surge tides overtopping the River Hull defences. It is approximately 30 metres wide and takes roughly 30 minutes to open or close. The Barrier is closed when a tidal level greater than 4.25 metres AOD is forecast. The Barrier was refurbished in 2009/2010. The highest tide in Hull since the Barrier was built was in December 2013 when a level of 5.805 metres AOD was recorded at the downstream side of the Barrier; the Hull Barrier was closed preventing the River Hull overtopping. The areas that benefit from the Hull Tidal Surge Barrier have been mapped for the 0.5% flood event for this SFRA (Figure 5).

A3.3 Humber frontage defences

Within the city the defences consist of a mixture of vertical sea walls and concrete revetments. Some of the defences have been raised by the construction of new wave return walls along the length of the crest of the existing structure. To the west, the defences abruptly change from sea walls to natural marshland. Along this length Clive Sullivan Way is on a raised embankment and effectively forms the defence. This embankment extends to Hessle Haven, where it affords protection to Waterside Business Park. The defences here consist of an unprotected earth embankment. The defences are varied in age, with the original dock structures dating mainly from the late 19th Century and the early 20th. The area along the east side of St Andrews Quay was improved between 1997 and 1999 and a new flood defences was built at Albert Dock after the December 2013 tidal surge. Whilst the new defences are in good condition, the original defences are generally in a poor condition. The area immediately to the west of the Hull Barrier consists of a mixture of different defences in poor condition. Part of the defence along this frontage is formed by the walls of various buildings and abandoned warehouses. The standard of protection excluding freeboard allowance is shown in Figure 1. This shows the current standard of protection of the Humber defences adjacent to Kingston upon Hull varies from 1 in 200 or greater in the west to less than 1 in 5 adjacent to Victoria Pier and the western part of Victoria Dock Village.

A3.4 Outfalls

The largest outfalls are those at the downstream ends of the Holderness Drain and the Beverley & Barmston Drain. These are 'flapped' to prevent flow going back up these drains during high tides.

A3.5 Other assets

In addition to the River Hull and Humber flood defences, the following assets within or adjacent to Hull City Council have a flood risk management aspect:

- Yorkshire Water surface water sewer system: provides drainage of surface water for urban areas within Hull.
- Beverley and North Holderness Internal Drainage Board drains: provides drainage for rural areas to the north of Hull City Council.
- Preston Internal Drainage Board drains: provides drainage for rural areas to the east of Hull City Council.
- Watercourses maintained by Hull City Council: provides drainage for urban and some rural areas within and adjacent to Hull and includes Counter Dyke and some sections of Fordyke Stream.

Only limited information on the above assets has been made available for this study. Consequently, the condition, standard of protection and likely future policy for these assets is not included within this study.

A4 Flood History

A list of historical fluvial, tidal and surface water flood events that have been recorded for Hull is given in Table 1 and Table 2 below. The River Hull water levels through the city are dominated by the tidal Humber levels and presently are not significantly affected by fluvial flooding, which is dominant in the headwaters and middle reaches of the River Hull. Since the installation of the Hull Tidal Surge Barrier in 1980, which protects the city from tidal surges, there has been no major overtopping of the River Hull due to tidal surges.

Immediate Source	Date	Location	Cause
River Hull	Sept 1969	Kingston upon Hull - areas adjacent to River Hull and Holderness Drain. Widespread flooding (855 houses).	Tidal surge propagating up the River Hull causing the defences to overtop.
Beverley & Barmston Drain	Feb 1997	North Hull.	Overtopping of bank tops.
Suttoncross Drain	unknown	Bransholme, around Noddle Hill Way/ Biggin Avenue/ Castlehill Road adjacent to Sutton Cross Drain.	This area apparently used to flood because the YWA pumps couldn't cope.
Setting Dyke	unknown	Willerby Road/Wymersley Road area and around the education centre, Coronation Road North near Setting Dyke.	Lack of maintenance of the trash screens and pumps.
Setting Dyke	Oct 2000	Localised flooding at Coronation Road.	Blocked trash screens.
Western Drain	Oct 2000	Localised flooding at Astral Close.	Blocked trash screens.
Acre Heads Drain	Oct 2000	The Ridings (flooding contained by sand bags).	Rising levels in the drain.
Holderness Drain	Oct 2000	Flooding of land around Carlam Hill.	Overtopping at low points in bank.
Suttoncross Drain	Oct 2000	Lapwing and Curlew Close on the Bransholme Estate (flooding contained by sand bags).	High water levels in the flood locked Sutton Cross Drain.
River Hull	various	Isolated areas adjacent to River Hull, mainly through industrial area.	Overtopping of defences during storm tides which were not high enough to trigger operation of the Hull tidal surge barrier. This is due to the poor condition of some of the defences.
Humber	Dec 2013	Overtopping and road flooding occurred to the St Andrews Quay retail park in the west and the Victoria Dock Village residential area to the east. The focus of	Tidal surge combined with high astronomical tide causing overtopping of the Humber defences and frontage.

Immediate Source	Date	Location	Cause
		flooding was the area from the west bank of the River Hull through to the St Andrews Quay site and into the city centre with a northerly extreme of Anlaby Road. Significant overtopping into Albert Dock at Riverside Quay causing ingress into English Street area and into the city centre and as far as Hessle Road to the west. Flood damage to 115 businesses and 149 residential properties has been recorded.	

Table 1 Flood history – tidal and fluvial (main river)

Immediate Source	Date	Location	Cause
Pluvial/Drains	15 June 2007	WEST HULL: Boothferry Road, Beverley Road, Anlaby Road, The Paddock, Meadowbank, Priory Road, Willerby Road, Newland Avenue, Cleveland Street, Normanton Rise, Westborough Way, Anlaby Common, Springhead Avenue, Chanterlands Avenue, Nunburnholme Park, Willerby Road (near Yorkshire Water Museum).	Heavy and sustained rainfall overloading drainage system.
Pluvial/Drains	15 June 2007	EAST HULL: Holderness Road, John Newton Way, Mount Pleasant, Hedon Road, Howdale Road.	Heavy and sustained rainfall overloading drainage system.
Pluvial/Drains	15 June 2007	NORTH HULL: Kingswood.	Heavy and sustained rainfall overloading drainage system.
Pluvial/Drains	25 June 2007	WEST HULL: Wymersley Road, Moorhouse Road, Hotham Road South, Hotham Drive, Wold Road, Coronation Road South, Coronation Road North, Meltonby Avenue, Birdsall Avenue, Brantingham Walk, Priory Road, Fern Hill Road, Appleton Road, Sorrel Drive, Celandine Close, Springhead Avenue, Kendal Way, Hawkshead Green, Legarde Avenue, Malham Avenue, Ingleton Avenue, The Paddock, Hessle Road, Belgrave Drive, Calvert Lane, Dunston Road, Boothferry Road, Anlaby Road, Kirklands Road, St George's Road,	Heavy and sustained rainfall overloading drainage system.

Immediate Source	Date	Location	Cause
		Bricknell Avenue, Northern Cemetery, Cottingham Road, Allotment and school playing field in Newland, Newland Avenue, Alexandra Road, Grafton Street, Lambert Street, De Grey Street, Pearson Park, Goddard Avenue, Ella Street, Victoria Street, Park Avenue, Westbourne Avenue, Prince's Road, Chesnut Avenue, Bricknell Avenue, Chanterlands Avenue.	
Pluvial/Drains	25 June 2007	EAST HULL: Swan Street, Chapman Street, Lincoln Street, Holderness Road, Hedon Road (at A1033 roundabout), The Oval and Elm Avenue, Laburnam Avenue, Westcott Street and School, Marlowe Street, East Park sports centre, Stockholme Road, West Carr Lane, Peppleton Close, Corona Drive, Dorchester Road, Holwell Road, Southcoates Avenue, Exeter Grove, Biggin Avenue, Kestrel Avenue, Church Street, Robson Way, Howdale Road, Mallyan Close, Ramsgate Close, Dunvegan Road, Gleneagles Park, Frome Road, Waveney Road, Western Gailes Way, Shannon Road (south), Salthouse Road and Holderness Road (near Holderness Drain), Jervis Road, School off Barham Road, Bradford Avenue, Ecclesfield Avenue.	Heavy and sustained rainfall overloading drainage system.
Pluvial/Drains	25 June 2007	NORTH HULL: Courtway Road, Hall Road, Orchard Park Road, Thorpepark Road, Ilthorpe, Homethorpe, Gorthorpe, Easethorpe, Dodthorpe, 14th and 8th Avenue, Princess Elizabeth Playing Fields, Parkstone Road, Welwyn Park Drive, Knightly Way, Chevening Park, Runnymede Way, Bushey Park, Roundabouts on Wawne Road, Hemble Way, Parcevall Drive, John Newton Way, Ashworthy Close, Cookbury Close, Bude Road, School off Bude Road, Bodmin Road, Tiverton Road, Blisland Close, Soffham Close, Hartland Close, Whitstone Close, Davidstow Close, Langtree Close, Cheltenham Avenue, Newtondale, Littondale, Stonesdale.	Heavy and sustained rainfall overloading drainage system.

Table 2 Flood history – surface water

Appendix B – Maps and Data explained

B1 Data collection and analysis

In order to provide an auditable and transparent evidence base for the assessment of flood risk, we collated all of the existing flood risk modelling outputs available from Hull City Council, East Riding of Yorkshire Council, Environment Agency and Yorkshire Water, including nationally available datasets.

We reviewed all the relevant information available and recorded data type, coverage, quality, age, detail, resolution, modelling method and limitations, return periods and agreement with equivalent datasets. This included identification of any issues and risks associated with its use.

We determined where newer data could be used to refresh the SFRA and where additional information could be derived from newer data. Through this analysis, we selected the most appropriate information available and highlighted where and why this information has been used to update the SFRA.

B1.1 Return Period Available

The standard return periods required to define Flood Zones 2, 3a and 3b are given in Table 3.

Flood Source	Flood Zone 1	Flood Zone 2 (outer boundary)	Flood Zone 3a (outer boundary)	Flood Zone 3b (Outer boundary)
Fluvial	>1 in 1000	1 in 1000	1 in 100	1 in 20 (with defences only)
Tidal	>1 in 1000	1 in 1000	1 in 200	N/A
Surface water	Not specified	Not specified	Not specified	Not specified

Table 3 Standard return periods required to define Flood Zones 2, 3a and 3b

Each flood data source made available to this study has been reviewed with reference to the return period requirements above. The findings are presented by flood source with fluvial and tidal sources split into a) with defences, and b) without defences (Table 4 to Table 7) and surface water flood sources in Table 8.

Data source	1 in 20	1 in 100	1 in 1000	Climate change
Old Fleet Drain Flood Mapping Study (2003) Defended scenario	1 in 25[1]	✓		1 in 100
River Hull FRM Strategy (2006) Defended scenario	✓	✓	✓	1 in 100
Setting Dike FW Improvements (2008) Defended scenario	1 in 25[1]	✓	✓	1 in 100
River Hull & Holderness Drain Flood Mapping (2012) – 'Defences operating' scenario.	✓	✓	✓	1 in 100
Anlaby and Kirk Ella Model Update (2013) Defended scenario	1 in 25[1]	✓		1 in 100
River Hull Integrated Catchment Strategy (2015) Baseline Fluvial scenario		✓		1 in 100
River Hull Frontages PAR (2014) Repaired breach scenarios (15 individual breaches)		✓[2]		Not sensitive to C.C.
Hull and Holderness Flood Alleviation Scheme (2015)[3] Do Minimum option	1 in 30[1]	✓	✓	1 in 100

Table 4 Return periods available – fluvial with defences

Notes for Table 4:
1: Will provide conservative estimate of Flood Zone 3b.
2: Actually modelled a 1 in 2yr fluvial return period but results very insensitive to return period.
3: This is an integrated fluvial – surface water model. The fluvial part of the flood extent has been estimated based on connectivity to main rivers.

Data source	1 in 100	1 in 1000	Climate change
Old Fleet Drain Flood Mapping Study (2003) Defended scenario (no undefended scenario)	✓		1 in 100
River Hull FRM Strategy (2006) Undefended scenario	✓	✓	1 in 100
Hull & Coastal Streams CFMP (2008) Undefended scenario	✓	✓	1 in 20, 100
Setting Dike FW Improvements (2008) Defended scenario (no undefended scenario)	✓	✓	1 in 100
East Hull Pumping Station / Bransholme Study (2011) – Do Nothing option	✓	✓	None
EA Flood Zone Map (2012)	✓	✓	None
River Hull & Holderness Drain Flood Mapping (2012) - Reach Removal Scenarios and Simplified 'All Defences Removed' scenario	✓	✓	None
Anlaby and Kirk Ella Model Update (2013) Undefended scenario	✓	✓	1 in 100
River Hull Frontages PAR (2014) Reach Removal Scenarios 4 and 5 (Hull)		✓	1 in 100, 1000
River Hull Integrated Catchment Strategy (2015) No Defences Fluvial scenario	✓		1 in 100
Hull and Holderness Flood Alleviation Scheme (2015)[1] Do Nothing option	✓	✓	1 in 2 only
Hessle Clough failure modelling (2015)[2] Hessle Clough Failure	✓	1 in 500	1 in 5, 20, 100, 500

Table 5 Return periods available – fluvial without defences

Notes for Table 5:
1: This is an integrated fluvial – surface water model. The fluvial part of the flood extent has been estimated based on connectivity to main rivers.
2: Flooding mechanism is tidal water propagating up the drain and overtopping banks of the drain. As the "pathway" for the floodwater is the drain, this flood source has been classified as fluvial.

Data source	1 in 200	1 in 1000	Climate change
Simple tidal inundation modelling (2007) Defended scenario	✓	✓	1 in 200
Humber North Bank Tidal Modelling (2012) Defended scenario	✓	✓	1 in 200
Humber North Bank Breach Modelling (2012) Repaired breach scenarios (18 individual breaches in vicinity of Hull City Council).	✓	✓	1 in 200, 1000
Hull Humber Frontages PAR (2015) 'Do Minimum unbreached' scenario	✓	1 in500	1 in 100, 200, 500
Hull Humber Frontages PAR (2015) Repaired breach scenarios (9 individual breaches)	✓[1]		1 in 100 for 2040 epoch
Humber North Bank Tidal Modelling Update (2015) Defended scenario	✓	✓	1 in 200

Table 6 Return periods available – tidal with defences

Notes for Table 6Table 5:

1: The present day climate 1 in 200yr event has not been modelled, but the 1 in 100yr return period for the 2040 epoch, which is very close to the present day 1 in 200yr event, has been modelled.

Data source	1 in 200	1 in 1000	Climate change
Simple tidal inundation modelling (2007) Undefended scenario	✓	✓	
EA Flood Zone Map (2012)	✓	✓	None
Humber North Bank Tidal Modelling (2012) Undefended scenario	✓	✓	1 in 200
Sunk Island Modelling (2013)	✓	✓	None
Hull Humber Frontages PAR (2015) 'Do Nothing defences failed' scenario			Fully undefended modelled for 2115 epoch only (1 in 200 and 500).
Humber Strategy update (2014) 'Do Nothing unrepaired breach' scenario	✓	✓	1 in 200, 1000
Humber North Bank Tidal Modelling Update (2015) Undefended scenario	✓	✓	1 in 200

Table 7 Return periods available – tidal without defences

Data source	1 in 2	1 in 30	1 in 100	1 in 200	1 in 1000	Climate change
Hull SFRA surface water modelling (2007)	✓		✓	✓		1 in 100
Hull SWMP (2009)	✓		✓	✓		1 in100
Areas Susceptible to Surface Water Flooding (2009)				✓		None
Flood Map for Surface Water (2010)		✓		✓		None
Integrated modelling for ERYC (2012)		1 in 25	✓	✓		1 in 100
Hull Holistic Drainage Study (2012)		1 in 25	✓	✓		1 in 100
East Hull Integrated Modelling (2013)		✓	✓		✓	None
Updated Flood Map for Surface Water (2013)		✓	✓		✓	None
River Hull Integrated Catchment Strategy (2015)[1,2] Integrated Model Baseline scenario			✓			1 in 100
Hull and Holderness Flood Alleviation Scheme (2015)[1] Do Minimum option	✓	✓	✓		✓	1 in 100

Table 8 Return periods available – surface water

Notes for Table 8:
1: This is an integrated fluvial – surface water model. The fluvial part of the flood extent has been estimated based on connectivity to main rivers.
2: This scenario has been modelled for two storm durations, the 10hr storm duration results could be used to define surface water flood risk while the 75hr storm duration results could be used to define fluvial flood risk.

B1.2 Climate change allowances

Some of the maps in this SFRA include the effects of climate change. The climate change allowances that should be used for the 2080s (2070 to 2115) taken from the Flood risk assessment climate change allowances (Environment Agency, April 2016) are:

- Sea level rise from 2015 to 2080s: 1.11m
- Increase in peak river flow for central allowance: 20%
- Increase in peak river flow for upper central allowance: 30%
- Increase in peak river flow for upper end allowance: 50%

Climate change assumptions used for key data sources are given in Table 9.

Data source	Modelled epoch	Guidance used	Flow increase	Sea level rise (m)	Notes
River Hull & Holderness Drain FM Study (2013)	2111	-	+20%	0.733	Flood outlined likely quite insensitive to SLR.
Anlaby & Kirk Ella Model Update (2013)	?	-	+20%	-	Fluvially dominated.
Setting Dike FW Improvements (2008)	?	FCDPAG4 (EA, 2003)	+20%	N/A	
Humber North Bank Tidal Modelling Update (2015)	2115	FCDPAG3 (EA, 2006)	N/A	1.1	
River Hull Integrated Catchment Strategy (2015)	2115	FCDPAG3 (EA, 2006)	+30%	≈ 1.0	
Hull and Holderness Flood Alleviation Scheme (2015)	2070s	Adapting to climate chg. (EA,2011)	+20%	0.45	Flood outlined likely quite insensitive to SLR.

Table 9 Climate change assumptions used.

The climate change allowances used in the existing modelling (Table 9) were considered sufficient for representing the central / upper central allowance of increase in peak river flow. Additional modelling was commissioned for this SFRA to represent the upper end allowance for increase in peak river flow for the 'with defences' situation for the following hydraulic models:

- River Hull & Holderness Drain
- Anlaby & Kirk Ella Model Update
- Setting Dike FW Improvements

B1.3 Data Source Comparison

In addition to review of available return periods, each flood data source made available to this study has been reviewed with reference to data type, coverage, quality, age, detail, resolution, modelling method and limitations. The findings are summarised by flood source with fluvial and tidal sources split into a) with defences (unbreached), and b) without defences (Table 10 to Table 14).

Data source	Not superseded	Appropriate return periods	Flood depth (D) and flood hazard (H) data	Model type	2D grid resolution	Recommend for SFRA	Comments
Old Fleet Drain Flood Mapping Study (2003) Defended scenario		✓		1d ISIS / 2d JFLOW	6m		Superseded
River Hull FRM Strategy (2006) Defended scenario		✓	D	1d ISIS	-		Superseded
Setting Dike FW Improvements (2008) Defended scenario	✓	✓	?	1d-2d ISIS-TUFLOW	4m	✓	
River Hull & Holderness Drain Flood Mapping (2012) 'Defences operating' scenario	✓ (part)	✓	D+H	1d-2d ISIS-TUFLOW	15m	✓	Model is superseded by RHICS (2015) model but the RHICS model is lower resolution and has not modelled all RPs required for SFRA.
Anlaby and Kirk Ella Model Update (2013) Defended scenario	✓		D	1d-2d ISIS-TUFLOW	4m	✓	
River Hull Integrated Catchment Strategy (2015) Baseline Fluvial scenario	✓		D+H	1d-2d Infoworks ICM	2 to 2000m^2	✓	With the exception of some features such as drains, the model resolution is typically lower than 500m^2 (compared to 225m^2 of River Hull & Holderness Drain Flood Mapping (2012).
Hull and Holderness Flood Alleviation Scheme (2015)[1] Do Minimum option	✓	✓	D+H	1d-2d Infoworks ICM	Urban: 25 to 100m^2	✓	Some extra GIS processing required.

Table 10 Data source comparison – fluvial with defences (unbreached)

Notes:
1: This is an integrated fluvial – surface water model. The fluvial part of the flood extent has been estimated based on connectivity to main rivers.

Data source	Not superseded	Appropriate return periods	Flood depth (D) and flood hazard (H) data	Model type	2D grid resolution	Recommend for SFRA	Comments
Old Fleet Drain Flood Mapping Study (2003) – Defended scenario (no undefended scenario)				1d ISIS / 2d JFLOW	6m		Superseded
River Hull FRM Strategy (2006) Undefended scenario		✓	D	1d ISIS	-		Superseded
Hull & Coastal Streams CFMP (2008) Undefended scenario		✓		2d TUFLOW	25m?		Superseded
Setting Dike FW Improvements (2008) Defended scenario (no undefended scenario)	✓	✓	?	1d-2d ISIS-TUFLOW	4m	✓	
East Hull Pumping Station / Bransholme Study (2011) – Do Nothing option.		✓		1d ISIS	-		Superseded
EA Flood Zone Map (2012)		✓		-	-		Superseded
River Hull & Holderness Drain Flood Mapping (2012) - Reach Removal Scenarios and Simplified 'All Defences Removed' scenario.	✓ (part)	✓	D+H	1d-2d ISIS-TUFLOW	15m	✓	Take maximum depth from Reach Removal scenarios 4 and 5 and from the Simplified 'All Defences Removed' scenario.
Anlaby and Kirk Ella Model Update (2013) Undefended scenario	✓		D	1d-2d ISIS-TUFLOW	4m	✓	
River Hull Frontages PAR (2014) Reach Removal Scenarios 4 and 5 (Hull)	✓	✓	D+H	1d-2d ISIS-TUFLOW	15m	✓	Same as River Hull & Holderness Drain Flood Mapping (2012) but climate change outline available.
River Hull Integrated Catchment Strategy (2015) No Defences Fluvial scenario	✓		D+H	1d-2d Infoworks ICM	2 to 2000m2	✓	1 in 1000 is not available; largest modelled is 1 in 100.
Hull and Holderness Flood Alleviation Scheme (2015)[1] Do Nothing option	✓	✓	D+H	1d-2d Infoworks ICM	Urban: 25 to $100m^2$	✓	
Hessle Clough failure modelling (2015)[2] Hessle Clough Failure	✓		D	1d-2d ISIS-TUFLOW	4m	✓	Use 2040 1 in 500 outline as approx of present day 1 in 1000 event.

Table 11 Data source comparison – fluvial without defences

Notes:
1: This is an integrated fluvial – surface water model. The fluvial part of the flood extent has been estimated based on connectivity to main rivers.
2: This flooding mechanism is tidal water propagating up the drain and overtopping the banks of the drain. As the "pathway" for the floodwater is the drain, this flood source has been classified as fluvial.
3: Risk of inconsistency with future EA Flood Zones.

Data source	Not superseded	Appropriate return periods	Flood depth (D) and flood hazard (H) data	Model type	2D grid resolution	Recommend for SFRA	Comments
Simple tidal inundation modelling (2007) Defended scenario		✓	D	1d ISIS	-		Superseded
Humber North Bank Tidal Modelling (2012) Defended scenario		✓	D+H	2d TUFLOW	10m		Superseded. Based on superseded extreme water levels (new water levels are significantly higher).
Hull Humber Frontages PAR (2015) 'Do Minimum unbreached' scenario	✓		D+H	2d TUFLOW	20m		1 in 500 available instead of 1 in 1000. Use 2040 1 in 500 outline as approx of present day 1 in 1000 event.
Humber North Bank Tidal Modelling Update (2015) Defended scenario	✓	✓	D+H	2d TUFLOW	10m	✓	Based on latest extreme water levels.

Table 12 Data source comparison – tidal with defences (unbreached)

Data source	Not superseded	Appropriate return periods	Flood depth (D) and flood hazard (H) data	Model type	2D grid resolution	Recommend for SFRA	Comments
Simple tidal inundation modelling (2007) Undefended scenario		✓	D	1d ISIS	-		Superseded
EA Flood Zone Map (2012)		✓		-	-		Superseded
Humber North Bank Tidal Modelling (2012) Undefended scenario		✓	D+H	2d TUFLOW	10m		Superseded. Based on superseded extreme water levels (new water levels are significantly higher).
Sunk Island Modelling (2013)	✓	✓	D	2d TUFLOW	30m	✓	Based on superseded extreme water levels (new water levels are significantly higher). Only use if they show greater flooding than Hull Humber Frontages PAR (2015) – this is unlikely.
Hull Humber Frontages PAR (2015) 'Do Nothing defences failed' scenario	✓		D+H	2d TUFLOW	20m		Not modelled for present day but modelled for 2040, i.e. with sea level rise of 0.16m. Use 2040 1 in 500 outline as approx of present day 1 in 1000 event.
Humber Strategy update (2014) 'Do Nothing unrepaired breach' scenario	✓	✓	D+H	MDSF2	50m		Lower resolution than other studies and simpler representation of hydraulics.
Humber North Bank Tidal Modelling Update (2015) Undefended scenario	✓	✓	D+H	2d TUFLOW	10m	✓	Based on latest extreme water levels.

Table 13 Data source comparison – tidal without defences

Notes:
1: Risk of inconsistency with future EA Flood Zones.

Data source	Not superseded	Appropriate return periods	Flood depth (D) and flood hazard (H) data	Model type	2D grid resolution	Recommend for SFRA	Comments
Hull SFRA surface water modelling (2007)		✓		2d TUFLOW	25m		Superseded
Hull SWMP (2009)		✓		2d TUFLOW	10–25m		Superseded
Areas Susceptible to Surface Water Flooding (2009)				2d JFLOW	5m		Superseded
Flood Map for Surface Water (2010)				2d JFLOW	5m		Superseded
Integrated modelling for ERYC (2012)		✓		1d-2d Infoworks ICM	2 to 600m^2		Superseded
Hull Holistic Drainage Study (2012)	✓	✓	D+H	1d-2d Infoworks ICM	2 to 600m^2		Incorporated into Updated Flood Map for Surface Water (2013)
East Hull Integrated Modelling (2013)	✓	✓	D+H	1d-2d Infoworks ICM	2 to 600m^2		We understand this was incorporated into Updated Flood Map for Surface Water (2013).
Updated Flood Map for Surface Water (2013)	✓	✓	D+H	Based on 1d-2d Infoworks ICM	2m	✓	Climate change not modelled.
River Hull Integrated Catchment Strategy (2015)[1,2] Integrated Model Baseline scenario	✓		D+H	1d-2d Infoworks ICM	2 to 2000m^2		Much lower resolution than Hull Holistic Drainage Study, which also used YW's AMP5 DAP sewer model.
Hull and Holderness Flood Alleviation Scheme (2015)[1] Do Minimum option	✓	✓	D+H	1d-2d Infoworks ICM	Urban: 25 to 100m^2		Much lower resolution than East Hull Integrated Modelling (2013), which also used YW's AMP5 DAP sewer model.

Table 14 Data source comparison – surface water

Notes:
1: This is an integrated fluvial – surface water model. The fluvial part of the flood extent has been estimated based on connectivity to main rivers.
2: This scenario has been modelled for two storm durations, the 10hr storm duration results could be used to define surface water flood risk while the 75hr storm duration results could be used to define fluvial flood risk.

B1.4 Repaired breach scenarios

Modelling of ‘Repaired breach’ scenarios is required to provide flood data for some of the maps included in this SFRA, including the Exception Test figure. Model results are required for the 1 in 100yr fluvial and 1 in 200yr tidal (or closest equivalent) return periods. Table 15 below lists and compares the sources of data available for present day climate.

Data source	Not superseded	Appropriate return periods	Flood depth (D) and flood hazard (H) data	Model type	2D grid resolution	Recommend for SFRA	Comments
River Hull Frontages PAR (2014) Repaired breach scenarios (15 individual breaches)	✓	✓	D+H	1d-2d ISIS-TUFLOW	15m		Results insensitive to return period and climate change.
Humber North Bank Breach Modelling (2012) Repaired breach scenarios (18 individual breaches in vicinity of Hull City Council).	✓	✓	D+H	2d TUFLOW	10-20m		Based on pre-2013 extreme water levels but can use 1000yr results to represent 200yr return period.
Hull Humber Frontages PAR (2015) Repaired breach scenarios (9 individual breaches)	✓	✓	D+H	2d TUFLOW	20m	✓	Can use the 100yr results for the 2040 epoch to represent 200yr results for present day climate.

Table 15 Data source comparison – repaired breach scenarios for present day climate.

For the future climate scenario, the River Hull breaches from the ‘River Hull Frontages PAR (2014)’ study were re-used as the results were shown to be insensitive to return period or climate change. Modelling of repaired breach scenarios of the Humber with allowance for climate change was commissioned for this SFRA. It was assumed that tidal flood defences would be raised in the future in line with sea level rise so that the modelled flooding was purely from breaching with no overtopping. The modelling used same breach locations that were used in the ‘Humber North Bank Breach Modelling (2012)’ and ‘Hull Humber Frontages PAR (2015)’ studies.

Details of the breach locations are given in Table 16.

ID	Description	Breach Length (m)	Assumed ground level (m AOD)	Asset Condition (1 is best; 5 is worst)
Breaches modelled in River Hull Frontages PAR (2014) (asset condition assessed in 2012)				
1	Disused outfall at Wincolmlee	10	2.8	4
2	Masonary wall	25	2.3	3
3	Bank Side Road	25	3.3	3

4	Low but narrow wall in chemical plant	25	2.9	5
5	Vulcan Street	25	1.8	3
6	East bank earth embankments	50	1.9	4
7	Housing estates behind western earth embankment	50	2.1	3
8	Masonry wall at back of dry dock	10	3.1	3
11	Steel piles with concrete capping	10	2.25	4
12	Old warehouse wall	10	3.5	4
13	Mass concrete wall with timber piling	25	3.8	4
14	Steel piles	25	4	3
15	Steel piles with concrete capping	25	2.2	4
16	Embankment, north Hull	50	3.1	3
17	Embankment, north Hull	50	2.5	3
Breaches modelled in Hull Humber Frontages PAR (2015) (asset condition assessed in 2014 / 2015)				
1	Paull	20	4.6	5
2a	Salt End	50	3.1	3
2b	Salt End	50	3.1	2
3	Alexandra Dock west	20	4.7	2
4	Victoria Dock Village west	20	5.0	2
5	Humber Street	20	4.6	1
6	William Wright Dock	20	4.85	3
7	Haven Shipbuilding Yard	20	4.6	3
8	Hessle east	50	3.8	4
Breaches modelled in Humber North Bank Breach Modelling (2012) (asset condition assessed in 2014 / 2015)				
HB15	Paull	20	4.63	2
HB16	Salt End	50	3.1	2
HB17	Lords Clough	20	4.4	2
HB18	King George Dock east	20	5.5	1
HB19	King George Dock west	20	5.62	1
HB20	Alexandra Dock east	20	5.5	1
HB21	Alexandra Dock west	20	4.8	2
HB22	Victoria Dock Village east	20	5.36	2
HB23	Victoria Dock Village west	20	5.1	2
HB24	Victoria Pier	2	4.84	3
HB25	Albert Dock	20	5.0	1
HB26	William Wright Dock	20	4.85	3
HB27	Dairycoates	20	5.13	3
HB28	Wasteland area	20	5.13	4
HB29	Clive Sullivan Way	20	3.44	3
HB30	Haven Shipbuilding Yard	20	6.26	3
HB31	Hessle east	50	5.25	4
HB32	Humber Bridge	50	5.2	2
HB33	Hessle west	50	5.22	2

Table 16 Breach location details.

B2 Data used in SFRA flood maps

Original (2007) Fig. No.	Update (2016) Fig. No.	Figure title (2016 title given if different from 2007 figure title)	Content	Return Periods	Data sources used in original SFRA (2007)	Data sources used in 2016 update	Notes, Risks and decisions
-	0	Ground levels	Ground levels from LiDAR (Light Detection and Ranging) Digital Terrain Model data.	N/A	-	LIDAR data	
4.3	1	Standard of protection	Standard of Protection of River Hull and Humber defences without freeboard allowance.	N/A	4.3	1	
5.5	2	Flood depths with defences	Maximum flood depths for fluvial and tidal flood sources assuming existing flood defences are present and do not fail.	Fluvial: 1 in 100 Tidal: 1 in 200	River Hull FRM Strategy (2006). Simple inundation modelling of Humber (2007). Old Fleet drain flood mapping study (2003).	River Hull & Holderness Drain FM Study (2013). Anlaby & Kirk Ella Model Update (2013). Setting Dike FW Improvements (2008). Humber North Bank Tidal Modelling Update (2015). River Hull Integrated Catchment Strategy (2015) Hull and Holderness Flood Alleviation Scheme (2015).	Some extra processing required for HaHFAS (2015) outputs.
5.7	3	Flood depths with defences with climate change	Maximum flood depths for fluvial and tidal flood sources assuming existing flood defences are present and do not fail. Includes allowance for climate change indicative of 2080s	Fluvial: 1 in 100+CC Tidal: 1 in 200+CC	River Hull FRM Strategy (2006). Simple inundation modelling of Humber (2007). Old Fleet drain flood mapping study (2003).	As per Figure 2.	Some extra processing required for HaHFAS (2015) outputs. Modelled sea level rise assumptions sometimes inconsistent with NPPG guidance.

Original (2007) Fig. No.	Update (2016) Fig. No.	Figure title (2016 title given if different from 2007 figure title)	Content	Return Periods	Data sources used in original SFRA (2007)	Data sources used in 2016 update	Notes, Risks and decisions
			to 2110s. In this figure, the central / higher central allowance for increase in river flow is used.				
-	3b	Flood depths with defences with climate change based on upper end fluvial flow increase	Maximum flood depths for fluvial and tidal flood sources assuming existing flood defences are present and do not fail. Includes allowance for climate change indicative of 2080s to 2110s. In this figure, the upper end allowance for increase in river flow is used.	Fluvial: 1 in 100+CC Tidal: 1 in 200+CC	-	As per Figure 2 plus additional modelling commissioned for this SFRA where the upper end fluvial allowance for climate change was simulated for the following models (see Appendix B1.2 for more details): • River Hull & Holderness Drain • Anlaby & Kirk Ella • Setting Dike	
5.8	4	Hull SFRA Flood Zone 3 with and without defences	Flood extents for with and without defences scenarios (fluvial and tidal).	Fluvial: 1 in 100 Tidal: 1 in 200	River Hull FRM Strategy (2006). Simple inundation modelling of Humber (2007). Old Fleet drain flood mapping study (2003).	River Hull & Holderness Drain FM Study (2013). Anlaby & Kirk Ella Model Update (2013). Setting Dike FW Improvements (2008). Humber North Bank Tidal Modelling Update (2015). River Hull Integrated Catchment Strategy (2015) Hull and Holderness Flood Alleviation Scheme (2015). Hessle Clough failure modelling (2015).	Some extra processing required for HaHFAS (2015) outputs. Risk of inconsistency with EA's Flood Zone maps.
5.9	5	Areas benefitting from Hull Tidal Surge Barrier in a 0.55% event	The areas benefitting from the Hull Tidal Surge Barrier in a 0.5% flood event.	Tidal: 1 in 200	River Hull FRM Strategy model (2007).	Hull Tidal Surge Barrier failure modelling (Arup, 2015)	Uses the updated Humber water levels. Figure to be re-titled.

Original (2007) Fig. No.	Update (2016) Fig. No.	Figure title (2016 title given if different from 2007 figure title)	Content	Return Periods	Data sources used in original SFRA (2007)	Data sources used in 2016 update	Notes, Risks and decisions
6.1	6	Flood depth for modelled breaches	Flood depth grid data for modelled breaches of the River Hull (fluvial) and Humber frontage (tidal).	Fluvial:1 in 100 Tidal: 1 in 200 (or nearest equivalent)	Hull SFRA breach modelling (2007).	Breach modelling results from: Humber North Bank Breach Modelling (2012) * [1] River Hull Frontages PAR (2014). Hull Humber Frontages PAR (2015). *[2]	Breach assumptions differ to those used in original SFRA. Note: *[1] 1 in 1000 used as based on old (lower) Humber water levels Note: *[2] Nearest available is 1 in 100.
-	6b	Flood depths for modelled breaches with climate change	Maximum flood depths for modelled breaches of the River Hull (fluvial) and Humber frontage (tidal) with allowance for climate change to 2116. Defence levels are assumed sufficient to prevent overtopping for the purposes of this figure. Flood depths are for modelled breaches only, flooding from overtopping of defences is not include in this figure.	Fluvial:1 in 100 Tidal: 1 in 200	-	River Hull Frontages PAR (2014) plus new Humber breach modelling commissioned for the updated 2016 SFRA (see Appendix B1.4 for more details).	
6.2	7	Flood velocity for modelled breaches	Flood velocity grid data for modelled breaches of the River Hull (fluvial) and Humber frontage (tidal).	Fluvial: 1 in 100 Tidal: 1 in 200 (or nearest equivalent)	Hull SFRA breach modelling (2007).	Breach modelling results from: Humber North Bank Breach Modelling (2012) * [1] River Hull Frontages PAR (2014). Hull Humber Frontages PAR (2015). *[2]	Breach assumptions differ to those used in original SFRA. Note: *[1] 1 in 1000 used as based on old (lower) Humber water levels Note: *[2] Nearest available is 1 in 100.
6.3	8	Flood hazard for modelled breaches	Flood hazard grid data for modelled breaches of the River Hull (fluvial) and	Fluvial: 1 in 100 Tidal: 1 in 200 (or nearest	Hull SFRA breach modelling (2007).	Humber North Bank Breach Modelling (2012) * [1] River Hull Frontages PAR (2014).	Breach assumptions differ to those used in original SFRA. Note: *[1] 1 in 1000 used as

Original (2007) Fig. No.	Update (2016) Fig. No.	Figure title (2016 title given if different from 2007 figure title)	Content	Return Periods	Data sources used in original SFRA (2007)	Data sources used in 2016 update	Notes, Risks and decisions
			Humber frontage (tidal).	equivalent)		Humber Hull Frontages PAR (2015). *²	based on old (lower) Humber water levels Note: *² Nearest available is 1 in 100.
7.10	-	Surface water flood depth 50% event	Flood depth grid data for surface water flooding.	Surface Water: 1 in 2	Hull SFRA surface water modelling (2007).	Figure omitted.	
7.11	-	Surface water flood depth 20% event	Flood depth grid data for surface water flooding.	Surface Water: 1 in 5	Hull SFRA surface water modelling (2007).	Figure omitted.	
7.11	-	Surface water flood depth 10% event	Flood depth grid data for surface water flooding.	Surface Water: 1 in 10	Hull SFRA surface water modelling (2007).	Figure omitted.	
7.12	-	Surface water flood depth 5% event	Flood depth grid data for surface water flooding.	Surface Water: 1 in 20	Hull SFRA surface water modelling (2007).	Figure omitted.	
7.13	9	Surface water flood depth 3.3% event	Flood depth grid data for surface water flooding.	Surface Water: 1 in 30*(originally was 1 in 25)*	Hull SFRA surface water modelling (2007).	Figure changed to show 30yr event. Updated Flood Map for Surface Water Flooding (2013). RHICS post WADFAS scheme data (100yr+CC only).	RHICS and HaHFAS (2015) outputs not used except at WADFAS scheme benefit area where RHICS data is used.
7.14	-	Surface water flood depth 2% event	Flood depth grid data for surface water flooding.	Surface Water: 1 in 50	Hull SFRA surface water modelling (2007).	Figure omitted.	
7.15	10	Surface water flood depth 1% event	Flood depth grid data for surface water flooding.	Surface Water: 1 in 100	Hull SFRA surface water modelling (2007).	Updated Flood Map for Surface Water Flooding (2013). RHICS post WADFAS scheme data (100yr+CC only).	RHICS and HaHFAS (2015) outputs not used except at WADFAS scheme benefit area where RHICS data is used.
7.16	11	Surface water	Flood depth grid data for	Surface Water: 1	Hull SFRA surface water	Figure changed to show 1000yr event.	RHICS and HaHFAS (2015)

Original (2007) Fig. No.	**Update (2016) Fig. No.**	**Figure title (2016 title given if different from 2007 figure title)**	**Content**	**Return Periods**	**Data sources used in original SFRA (2007)**	**Data sources used in 2016 update**	**Notes, Risks and decisions**
		flood depth 0.1% event	surface water flooding.	in 1000 *(originally was 1 in 200)*	modelling (2007).	Updated Flood Map for Surface Water Flooding (2013). RHICS post WADFAS scheme data (100yr+CC only).	outputs not used except at WADFAS scheme benefit area where RHICS data is used.
7.17	-	Surface water flood depth – 1% flood depth with climate change	Flood depth grid data for surface water flooding.	Surface Water: 1 in 100+CC	Hull SFRA surface water modelling (2007).	Not included in latest data source. Figure omitted.	Inconsistency if we retain this figure. Raw model result available for West Hull but not East Hull.
7.19	-	Surface water flood risk zones	Low, Medium and High surface water flood risk zones based on depth.	Surface Water: 1 in 200	Hull SFRA surface water modelling (2007).	Figure omitted.	
8.1	-	Flood Zones without surface water	Flood Zones 2, 3a and 3b. Flood Zone 3a split into low, medium and high hazard (fluvial and tidal).	Fluvial: 20, 100 and 1000. Tidal: 200, 1000.	River Hull FRM Strategy (2006). Simple inundation modelling of Humber (2007). Old Fleet drain flood mapping study (2003). Hull SFRA breach modelling (2007).	Figure omitted.	Definition of low, medium and high hazard areas within Flood Zone 3a to consider consequence & probability.
-	13	Exception Test figure	Maximum flood depths from the sources listed below plus the remaining areas of Flood Zones 2 and 3a and Flood Zone 3b and the main river 20m buffer strip. 1) Overtopping with current defence levels for present day climate. 2) Overtopping with current defence levels with allowance for climate	Fluvial: 1 in 100 and 1 in 100+CC Tidal: 1 in 200 and 1 in 200+CC Surface water: 1 in 1000	-	Maximum flood depths: • All data sources used in Figure 2. • All data sources used in Figure 3b. • All data sources used in Figure 6b. • Updated Flood Map for Surface Water Flooding (2013). Flood Zones 2, 3a and 3b: Please refer to the data sources used for Figure 14.	

Original (2007) Fig. No.	Update (2016) Fig. No.	Figure title (2016 title given if different from 2007 figure title)	Content	Return Periods	Data sources used in original SFRA (2007)	Data sources used in 2016 update	Notes, Risks and decisions
			change to 2116. The upper end fluvial flow increase (50% increase) scenario is used where available. 3) Breaching of defences with allowance for climate change to 2116. This is based on the assumption that the Humber defences are raised to mitigate sea level rise so that there is no overtopping. 4) Surface water for 0.1% rainfall event for present day climate.				
8.2	14	Flood Zones for Sequential Test	This map is for use in applying the Sequential Test and shows Flood Zones 1, 2, 3a and 3b based on fluvial, tidal and surface water flood sources. Flood Zone 3a split into 4 sub zones; the split is based on flood depths for present day climate, assuming current defence levels, from the following flood sources: • Overtopping of defences • Breaching of defences • Surface water	Fluvial: 1 in 5, 1 in 100 and 1 in 1000. Tidal: 1 in 200 and 1 in 1000. Surface Water: 1 in 1000.	Same as Figures 7.19 and 8.1.	River Hull & Holderness Drain FM Study (2013). Anlaby & Kirk Ella Model Update (2013). Setting Dike FW Improvements (2008). Humber North Bank Tidal Modelling Update (2015). River Hull Integrated Catchment Strategy (2015) Hull and Holderness Flood Alleviation Scheme (2015). Hessle Clough failure modelling (2015). Definition of Flood Zone 3a sub-zones split: Please refer to Appendix B3.	Definition of low, medium and high hazard areas within Flood Zone 3a does not consider probability of breach.
10.3	-	Flood Zones	As Figure 8.2 but with	As for Figure 8.2.	As for Figure 8.2.	Figure omitted.	

Original (2007) Fig. No.	Update (2016) Fig. No.	Figure title (2016 title given if different from 2007 figure title)	Content	Return Periods	Data sources used in original SFRA (2007)	Data sources used in 2016 update	Notes, Risks and decisions
		including surface water risk with strategic development areas	Strategic Development Areas overlaid.				
-	15	Floor levels for ‘places of safety’	Map showing floor levels required for ‘places of safety’ excluding supplementary requirements for surface water flood risk. Floor levels are based on the maximum water level for the defended situation and the repaired breach situation for the 0.1% event (or the most extreme available) including allowance for climate change representative of the year 2115.	0.1%+CC (or closest equivalent)	-	River Hull & Holderness Drain FM Study (2013). Anlaby & Kirk Ella Model Update (2013). Setting Dike FW Improvements (2008). Humber North Bank Tidal Modelling Update (2015). River Hull Integrated Catchment Strategy (2015) Hull and Holderness Flood Alleviation Scheme (2015). Hessle Clough failure modelling (2015).	

B3 Zone Splitting Approach

This section summarises the approach used for splitting Flood Zone 3a into 4 sub-zones to enable application of the Sequential Test: FZ3a i (low), FZ3a ii (medium-1), FZ3a iii (medium-2) and FZ3a iv (high) where FZ3a i represents the lowest risk category within FZ3a and Z3a iv represents the highest risk category within FZ3a. A set of criteria to define these risk areas was agreed with the Environment Agency and is described below.

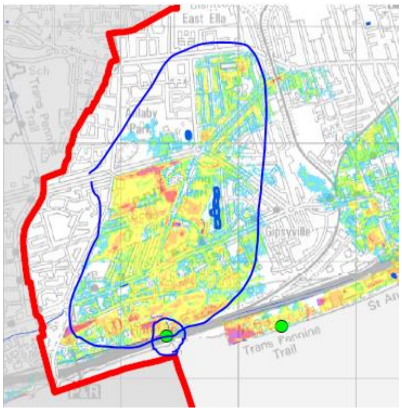
Key assumptions are:

- The consequences of the River Hull and Humber Frontages breaching is considered but the probability of breaches is not considered.
- The zone splitting is based on the design flood depths from each flood source below.
- The design flood depths used are for present day climate, i.e. they do not include allowances for climate change. This was also the case in the 2007 SFRA.

The flood sources used in the zone splitting are:

1) Overtopping of rivers and Humber estuary: This is the same data as that shown in Figure 2 'Flood depths with defences', which is based on a 1% fluvial event and a 0.5% tidal event for present day climate, assuming that these defences are not raised in line with the investment proposals being developed by the Environment Agency.

2) Breaches of River Hull and Humber estuary: This is the same data as that shown in Figure 6 'Flood depths for modelled breaches' for all but one breach. This figure includes the River Hull PAR and Humber PAR breaches and the Humber North Bank Breach Modelling breaches, which have been modelled for present day climate. Breach probability has not been considered. One of the Mott MacDonald breaches (shown below) was omitted as the breach scenario is not considered credible for present day climate. The defence line here comprises the dual carriageway (A63) which is raised to a level of over 5m AOD.



3) Surface water flood risk: This is the same data as that shown in Figure 10 ‘Surface water flood depths 1%’, which is based on the Environment Agency’s Updated Flood Map for Surface Water Flooding.

The design flood depths for each of the above 3 flood sources were merged to give the maximum flood depth of any flood source at each location, i.e. Depth at any point = Maximum of (overtopping depth, breaching depth, surface water depth). The four FZ3a sub-zones were then created based on the flood depth classification given in Table 17.

Table 17: FZ3a sub-zone descriptions.

Zone	Description
FZ3a i (low)	All areas in Flood Zone 3a that are not within the other three sub-zones, i.e. no flooding in the design event for the three flood sources described above but still within FZ 3a.
FZ3a ii (medium-1)	Flood depth between 0.0m and 0.3m.
FZ3a iii (medium-2)	Flood depth between 0.3m and 0.6m.
FZ3a iv (high)	Flood depth greater than 0.6m.

The FZ3a sub zones have been “cleaned” to remove holes and puddles that are $400m^2$ or smaller.

Appendix C– Links to other Documents

C1 Relevant documents

Links to other relevant documents can be found in the table below.

Title	Link
Hull Surface Water Management Plan	http://www.hullcc.gov.uk/portal/page?_pageid=221,638936&_dad=portal&_schema=PORTAL
River Hull Integrated Catchment Strategy (RHICS)	http://www2.eastriding.gov.uk/EasySiteWeb/GatewayLink.aspx?alId=601531
Local Flood Risk Management Strategy	http://www.hullcc.gov.uk/portal/page?_pageid=221,1429916&_dad=portal&_schema=PORTAL
Humber FRM Strategy	https://www.gov.uk/government/publications/humber-flood-risk-management-strategy
NPPF Planning Practice Guide	http://planningguidance.communities.gov.uk/

Appendix D– Glossary of Terms and Abbreviations

D1 Terms and Abbreviations

Term / Abbreviation	Definition
DCLG	Department of Communities and Local Government
DIA	Drainage Impact Assessment
EA	Environment Agency
ERYC	East Riding of Yorkshire Council
FRA	Flood Risk Assessment
HCC	Hull City Council
LLFA	Local Lead Flood Authority
LPA	Local Planning Authority
NPPF	National Planning Policy Framework
PPG	Planning Practice Guidance
RHICS	River Hull Integrated Catchment Strategy
SFRA	Strategic Flood Risk Assessment
SuDS	Sustainable Drainage Systems