East Riding of Yorkshire Council Strategic Flood Risk Assessment (SFRA) Level 2 – Goole

July 2011

Document Reference: B1166100/TASK04/D03

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Document Control Sheet

BPP

Client:	East Riding of Yorkshire Council			
Project:	Strategic Flood Risk Assessment		Job No:	B1166100
Document Title:	Level 2 - Goole			

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Document Status: FINAL issue to Client				

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DATE **September 2010**	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE
Document Status: FINAL issue to Client				

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DATE **January 2011**	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE
Document Status: FINAL issue to Client				

Introduction

1. This Level 2 Strategic Flood Risk Assessment (SFRA) considers the town of Goole, a key focus for development and regeneration within the East Riding that is nestled between the River Ouse, the River Aire and Dutch River and falls almost entirely within Flood Zone 3 High Probability[1]. It builds upon the findings of the Level 1 SFRA (published in January 2010) and the Environment Agency's National Flood Map (reviewed quarterly), and forms an important part of the evidence base for the East Riding of Yorkshire Local Development Framework.

2. Planning Policy Statement (PPS) 25: *Development and Flood Risk* encourages Local Planning Authorities to apply a Sequential Test when preparing their LDFs (informed by a Level 1 SFRA) to ensure that development is steered to areas of lowest flood risk, as far as possible. In places such as Goole however, where this is not possible (due to there being little land available outside Flood Zones 2 and 3), PPS25 recommends that a more detailed study should be undertaken - a 'Level 2' SFRA. A Level 2 SFRA provides a better understanding of flood risk, for instance, taking into account the benefits offered by any existing flood defences and assessing what the likely flood hazard would be to people and property if, in a 'worst case scenario', such defences were to fail. In particular, a Level 2 SFRA helps to assess whether it will be possible for developments to meet part 'c' of the PPS25 Exception Test (required for some types of development in Flood Zones 2 and 3).

> **The PPS25 Exception Test**
>
> To pass the Exception Test, the following criteria must be satisfied:
>
> a. *It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk;*
>
> b. *the development should be on developable, previously developed land or if it is not on previously developed land, that there are no reasonable alternative sites on previously developed land; and*
>
> c. *a Flood Risk Assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere, and where possible, will reduce flood risk overall."*

3. **The primary objective of this Level 2 SFRA, therefore, is to ensure that the risk of flooding in Goole can be realistically mitigated through the design process**.

[1] See the Environment Agency's National Flood Map at: http://www.environment-agency.gov.uk/homeandleisure/37837.aspx

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Adopted Methodology

4. As outlined in Section 5.2 of the Level 1 SFRA, the speed and depth with which floodwaters affect developed areas of the Authority area is an important consideration. Deep, fast flowing water may potentially pose risk to life. This must be considered when planning future development. The town of Goole (and surrounding villages) is situated at the confluence of the River Ouse, the River Aire and the Dutch River. The town is protected against flooding by a series of raised flood defences. If these flood defences were to fail, areas immediately behind the defences and low lying areas within the town would be at risk of flooding. The potential impact that rising sea levels will have upon the standard of protection currently provided by the flood defences has also been considered as part of this investigation.

5. A two dimensional TuFLOW model has been prepared to assess the extent, depth and speed of floodwaters as a result of the overtopping and/or breach of the River Ouse, River Aire and Dutch River defences. In accordance with PPS25, all analyses have been carried out assuming a 0.5% Annual Exceedance Probability (AEP) (1 in 200) design tidal event, representing the worst combination of possible tidal and/or fluvial scenarios for the three river systems, appropriate for the consideration of development proposals. The design flow regime, and the hydraulic characteristics of the main river channel, were adopted from existing Environment Agency ISIS models of the river systems. The development of the adopted TuFLOW model is set out in Appendix A.

6. To assess the risk that the floodwaters pose to life, an assessment of flood hazard has been carried out using the adopted 2D model. The 'hazard' posed by flooding is determined as a product of the depth and the speed of the flow[2], and assessed in accordance with Defra guidance 'Flood Risk to People (FD2320). The hazard categories adopted for SFRA purposes are outlined below:

Flood Hazard Rating	Flood Hazard	Description
<0.75	Low	**Caution:** *Flood zone with shallow flowing water or deep standing water*
0.75 – 1.25	Moderate	**Dangerous for Some (e.g. children, the elderly and infirm):** *Danger: Flood zone with deep or fast flowing water*
1.25 – 2.0	Significant	**Dangerous for Most (e.g. the general public):** *Danger: flood zone with deep fast flowing water*
>2.0	Extreme	**Danger to All (includes emergency services):** *Extreme Danger: flood zone with deep fast flowing water*

7. A total of ten breach locations have been modelled as set out in Appendix A. The risk of flooding due to overtopping in the 0.5% (1 in 200) and 0.5% plus climate change (in 100 years) design events, has also been considered.

8. The hydraulic modelling outputs for the hazard zones were 'contoured' to remove the gaps between the modelled breach locations. The findings of the detailed Level 2 assessment are summarised below.

[2] Hazard = (Depth(m) x (Velocity(m/sec)+0.5)) + DF)

Level 2 SFRA Findings

Overtopping of the Existing Flood Defences (2008)
Refer Figures A.1 (Flood Depth) & A.2 (Flood Hazard) in Appendix B

9. The existing flood defences do not overtop in the 0.5% (1 in 200) design event within Goole itself. This confirms that the defences currently provide at least a 0.5% (1 in 200) standard of protection to Goole.
10. Areas to the west of Goole and to the east of the town (on the River Ouse) do experience some flooding in the 0.5% (1 in 200) design event. Whilst these areas are not an intended focus for the current investigation, these findings should be used to inform any potential future planning decisions within the East Riding.

Overtopping of the Existing Flood Defences (Climate Change, 2108)
Refer Figures B.1 (Flood Depth) & B.2 (Flood Hazard) in Appendix B

11. An increase of 1.03m over the current 0.5% (1 in 200) sea level is predicted as a result of climate change[3] over the next 100 years. The overtopping of the existing flood defences in this event has been assessed. It is clear that a relatively large proportion of the existing flood defences will need to be raised if the 0.5% (1 in 200) standard of protection is to be maintained through to 2108.
12. A comprehensive review of flood risk management related policies from relevant strategy documents published by the Environment Agency, including The Humber Flood Risk Management Strategy (March 2008) and the draft River Ouse Catchment Flood Management Plan (CFMP) (July 2010), has found that there are long term intentions to continue to provide protection to the current annual exceedance probability (AEP), and keep pace with climate change. This demonstrates a commitment to adapt/improve defences to ensure the same standard of protection is sustained into the future. However, regardless of the continuing protection provided by the defences, the majority of Goole remains classified as Flood Zone 3[4].
13. The Humber Strategy highlights that improving the defences will be expensive and that contributions will be sought to supplement public funds “from major beneficiaries and from developers, who will be expected to pay the full cost of any new works needed to protect their development”. The Council’s approach to developer contributions is to be established through the Local Development Framework (Core Strategy), informed by an Infrastructure Study and financial viability assessment. The Infrastructure Study (currently in preparation) focuses on a range of infrastructure (including flood risk management infrastructure) that may be needed to support the level of development proposed in the East Riding to 2026.

Breach Failure of the Existing Flood Defences
Refer Figures C.1 to L.1 (Flood Depth) & C.2 to L.2 (Flood Hazard) in Appendix B

14. The consequence of a breach failure of the existing flood defences has been assessed through hydraulic modelling at ten (10) agreed breach locations. The location of the breaches, the adopted configuration of the assumed breach failures, including the breach width, and the length of time assumed between failure and emergency repair of the defence are described in Appendix A. It is highlighted that a large proportion of the flood defences within the Goole area feature a large berm on the river frontage. Discussions were held with the Environment Agency to agree the most realistic failure scenario for these defences in this instance, and this is depicted in the figure below.

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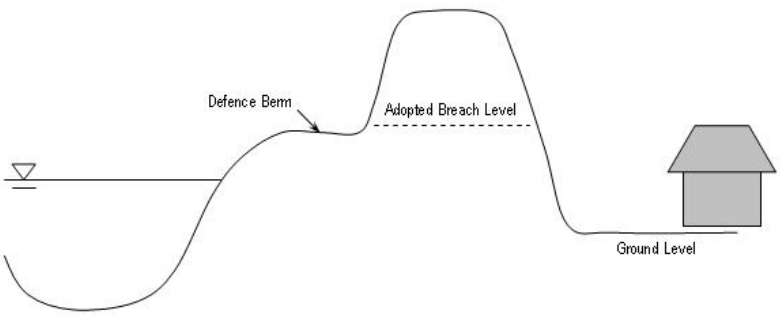
[3] PPS25 Appendix B

[4] The PPS25 Flood Zones ignore the presence of flood defences

15. The time during the flood event at which the breach occurred in the modelling was chosen such that it would create the worst case scenario. However, the time that generates the worst case in terms of depth of flooding is different to the time which creates the worst case in terms of velocity.

16. For flood depth and extent, it was assumed that the breach has already occurred prior to the high tide, as this would allow more water through the breach and create the largest extent. For the hazard maps it was assumed that the breach occurred at the peak of the tide. The sudden failure of the defences at the high tide would create the maximum velocities, but not necessarily the largest extent. The results for the two separate model scenarios were created and the outputs combined to create the worst case hazard map. The approach is described further in Appendix A.



17. The consequence of failure of the existing flood defences, at the ten locations identified in Appendix A, is presented in the figures in Appendix B. The depth of flooding within Goole is represented in Figures C.1 to L.1, and the flood hazard (calculated in accordance with FD2320, as set out in Appendix A) is represented in Figures C.2 to L.2. Figure N shows the combined flood hazard of all the ten breach locations.

18. As expected, it is clear that a relatively large proportion of Goole, and the surrounding area, is potentially at risk of flooding if the raised defences were ever to fail. The assessment of flood hazard confirms that, if a breach were to occur, the depth and velocity of the flow within these areas may pose a potential risk to property and life. The Environment Agency would be responsible for managing the repair operation in such a situation. The response time would be dependant on a number of factors including: ease of access, availability of suitable materials and available staff and plant resources. Other factors that might impede the rate of repair could be: extreme weather, number of breaches and type of breach.

19. Also, there is no natural means for water to flow back into the river, therefore the area would be inundated for an extended period, and would require artificial pumping to drain the area. All areas that are potentially at risk of flooding following a breach failure would be inundated within a 6 hour period (see Figure M), and therefore the available warning time for residents is limited.

20. In light of these findings it is emphasised that the flood defences around Goole are, according to The Humber Flood Risk Management Strategy (March 2008) “generally in good condition and provide a good standard of protection”, and, as mentioned above, there is a commitment to continue to maintain the defences to a good standard into the future. It is therefore not considered likely that such a breach event would ever occur, but these findings are useful in enabling the Council and other relevant organisations to plan for the ‘worst case scenario’. Specific recommendations for managing flood risk through the development planning process in Goole are provided in the next section.

Recommended Planning Response

21. It has been highlighted that Goole's formal defences offer a 0.5% AEP (1 in 200 year) standard of protection and that they would be overtopped in a 0.1% AEP (1 in 1000 year) event. The EA are committed to maintaining the current standard of protection of the town and to modify defences to keep up with climate change predictions. However, as the benefits from defences are not considered in the Flood Zone classifications, Goole remains classified as Flood Zone 3 High Probability. It has also been highlighted that a substantial part of the town would be subject to flooding in the event of any breach(es) of the town's defences.
22. It is therefore essential that future development within Goole considers the potential hazard (denoted as Danger to All, Danger to Most and Danger to Some on the maps at Appendix B) as a result of flooding. Developments should be considered on a site-specific basis in respect to appropriate land uses to prevent vulnerable developments being located within potentially hazardous areas. Also, it will be necessary to mitigate a site's flood hazard through the design of new developments.
23. The following sections contain more information on the appropriate planning response with consideration of the results obtained from the hydraulic modelling undertaken as part of this Level 2 SFRA.

Development in Rapid Inundation Zones

24. It is recommended that no development is allowed in the Rapid Inundation Zone. This area will experience the worst potential depths, velocities and debris, which may pose a risk even to water-compatible developments. Instead of developing this area it could be more suitable for open spaces and landscaped gardens. This would reduce the risk to people and, reduce the risk for others if the land use was vegetated, by further slowing the velocity of the water moving into other areas. Note that for Goole, a notional 20m has been assumed as the Rapid Inundation Zone, as no further guidance can be found to define the extent.

Development in 'Danger to All ', 'Danger to Most' and 'Danger to Some' Areas

25 Figure N (- Combined flood hazard for defence breaches) should be used as the principal map for identifying whether a site is situated in one of these flood hazard classifications, as this map depicts the 'worst case scenario' for Goole.

26. In areas where the level of flood hazard has been classified as 'danger to all', it is recommended that the council should adopt a policy to strongly resist development. In a minority of cases (i.e. in exceptional circumstances), development *may* be appropriate (assuming the Sequential Test and Exception Test have both been passed). However, 'more vulnerable' land uses (refer to annex D of PPS25) should not be located at ground floor level.
27. In areas that have been classified as 'danger to most', 'more vulnerable' development (e.g. residential) should avoid habitable uses at ground floor level. The Building Regulations (part 'M') define habitable uses as rooms used for dwelling purposes, including bedrooms and kitchens but not bathrooms or utility rooms. The Environment Agency generally adopts this definition. A planning condition would need to be applied to prohibit habitable accommodation at ground floor.
28. In the 'danger to some' areas, 'more vulnerable' development can be considered without ground floor restrictions, but only if the buildings have more than one storey so that there is available access to a floor above the predicted flood level.

29. In all instances the Council should not consider any planning application in the 'danger to all', 'danger to most', and 'danger to some' areas without an accompanying FRA which

clearly acknowledges the level of residual risk (flood hazard) and includes appropriate mitigation measures. Appropriate mitigation measures could include:

- Electrical circuits lowered from the ceiling, raised sockets
- Reinforced structural elements of building to withstand loading during a flood event
- Flood gates to doors
- Air brick covers
- Horizontal plaster boards
- Damp proof membranes.

30. The effectiveness of the mitigation measures should be backed up with evidence included in the FRA, such as engineering reports (if necessary), that the proposed measures are appropriate and can withstand the expected depth and velocity should there be a breach of the defences around Goole. Consideration should also be made for evacuation routes out of a site that has applied mitigation measures.

31. Developers and planners seeking advice on appropriate mitigation measures should be guided to the following document in the first instance:

    'Improving the Flood Performance of New Buildings', Flood Resilient Construction (May 2007).

Development Across Multiple Hazard Zones

32. Development proposals and FRAs should have regard to how flood hazard varies within a site. Where part of a development encroaches on areas classified as 'danger to all' the Council should ensure the following:

    - Any development classified as 'more vulnerable' is resisted (in the Danger to All part)
    - A sequential approach is applied at the site level. i.e. the more vulnerable types of land use are located in the areas of lowest flood hazard
    - Changes to flood hazard as a result of the development are clearly identified both within the proposed site itself and areas outside of the development.

Additional Considerations

33. Consideration should also be given to resilience to all sources of flooding, for example surface water and groundwater, as well as fluvial and tidal flooding. The Level 1 SFRA contains information on potential and historic flooding from other sources.

34. Consideration should also be given to emergency planning arrangements, as the construction of "more vulnerable developments" in areas of residual flood risk may have implications for the existing Emergency Plans. A review of the Emergency Planning in place for the East Riding is available in the SFRA Level 1 (Section 6.8), which outlines the responsibilities of different government bodies.

35. Any policy or guidance developed by East Riding of Yorkshire Council should be subject to continual review and updating to ensure it reflects the latest guidance.

Decision Matrix

36. The Level 2 SFRA's planning recommendations are summarised in the matrix provided below. This largely mirrors the matrix at Section 6.4.4 of the Level 1 SFRA (January 2010). If the proposal is on a site that falls outside the Level 2 SFRA's flood hazard classifications (i.e. not shown as a colour on any of the maps), the Environment Agency's Flood Map should be accessed to identify which Flood Zone applies to the site. In the majority of cases, this will be Flood Zone 3a, as only a very small proportion of Goole is classified as Flood Zone 1 or 2.

PPS25 Requirement	PPS25 Flood Zone							
	TIDALLY DOMINATED FLOOD RISK (Flood Zone 3a)						Flood Zone 2 (See EA Flood Map)	Flood Zone 1 (See EA Flood Map)
	Areas in Close Proximity to Defences					Remaining Flood Zone 3a (See EA Flood Map)		
	Rapid Inundation Zone	Danger to All	Danger to Most	Danger to Some	Caution			
SPATIAL PLANNING RECOMMENDATIONS								
Important Considerations	No development - reserved for open space / landscaping	Future development within areas at risk of tidal flooding can only be considered following application of the Sequential Test					Future development within Zone 2 Medium Probability can only be considered following application of the Sequential Test	It is important to recognise that sites within Zone 1 may be susceptible to flooding from other sources. Development may contribute to an increase in flood risk elsewhere if not carefully mitigated
Land Use (refer Table D2 of PPS25)		Land use should be restricted to Water Compatible, Essential Infrastructure or Less Vulnerable development. More Vulnerable development may only be considered if Exception Test can be passed					Land use should be restricted to Water Compatible, Less Vulnerable, Essential Infrastructure or More Vulnerable development. Highly Vulnerable development may only be considered if Exception Test can be passed	No restrictions
		Development will only be permitted in this zone in exceptional circumstances Habitable development should not be permitted at ground level	More vulnerable development should not be permitted in single storey buildings; habitable uses should not be permitted at ground level in multi-storey buildings	More vulnerable development should not be permitted in single storey buildings	~	~		

DEVELOPMENT CONTROL RECOMMENDATIONS					
Detailed Flood Risk Assessment (FRA)	N/a	Required			Required for all sites greater than 1ha in area, and/or situated within the Groundwater Emergence Zone, and/or a Surface Water Hazard Zone.
Floor Level and flood proofing	N/a	To be agreed on a site by site basis and to be informed by Figures N & O		Finished floor levels to be set at 300mm above average site level or adjacent road frontage level, whichever is higher. (Road frontage level defined as the average between the gutter and the crown of the road).	No minimum level stipulated by PPS25
Site Access & Egress	N/a	A safe refuge should be available on an upper floor, providing an immediate route of escape should a breach failure occur	To ensure the safety of residents and employees during a flood, access and egress routes must be designed to meet Environment Agency defined criteria, as set out in Appendix E. It is essential to ensure that the nominated evacuation route does not divert evacuees onto a 'dry island' upon which essential supplies (i.e. food, shelter and medical treatment) will not be available for the duration of the flood event.		No minimum level stipulated by PPS25
Basements	N/a	Basements are subject to rapid inundation without warning within this zone, and should not be permitted	Separate dwellings should not be permitted at basement level. All basements must have an access point that is above the 1 in 100 year fluvial, or 1 in 200 year tidal (whichever is greater) flood level, including climate change	No restrictions	No restrictions
Site Runoff	N/a	Implement SuDS on all sites unless it can be demonstrated that they are not practicable or that they will present an unacceptable pollution risk to controlled waters. Development on greenfield sites will be expected to restrict runoff to the greenfield runoff rate. Developments on brownfield sites will be expected to reduce existing runoff rates by a minimum of 30% in order to tackle the predicted impacts of climate change. Any SuDS design must take due account of groundwater and geological conditions (refer Section 6.6.3). It should be ensured that all developments adequately mitigate for the additional volume of surface water generated, not just the rate at which it runs off, to ensure that existing receiving waters are not over burdened.			
Buffer Zone	N/a	A minimum 8m buffer zone from the bank top of a main river or landward toe of a flood defence should be provided within sites immediately adjoining a river corridor. This relates to both open waterways and culverted waterway corridors. Reference should be made to the Environment Agency's "Living on the Edge" guide (www.environment-agency.gov.uk) that discusses any development situated in, over, under or adjacent to rivers and/or streams. This requirement may be negotiated with the EA in heavily constrained locations.			
Other	N/a	Ensure that the proposed development does not result in an increase in maximum flood levels within adjoining properties. This may be achieved by ensuring (for example) that the existing building footprint is not increased, that overland flow routes are not truncated by buildings and/or infrastructure, or hydraulically linked compensatory flood storage is provided within the site (or upstream)			
	N/a	As an integral part of the government's "Making Space for Water" agenda, the Environment Agency is actively seeking the renaturalisation of culverted watercourses as part of any future development. Realistic opportunities to reinstate the natural open waterway within existing culverted reaches of the river(s) should be promoted			

APPENDIX A
Modelling Approach & Assumptions

1. Summary of modelling approach

A hydraulic model was constructed to establish the residual flood risk from breaches and overtopping. A one dimensional (1D) hydraulic model of the Lower Ouse River channel and two of its tributaries the River Dutch and River Aire was dynamically linked to a two dimensional (2D) model of the floodplain within the Goole area using Tuflow 2D modelling software. At ten specific locations, a breach in the flood defence line protecting Goole was artificially created assuming failure at river berm level. For each breach location, flooding across the floodplain was then simulated with the hydraulic model, assuming 0.5% annual probability (200 -1 annual chance) tidal surge conditions in the river system.

2. Overview of the 1D model

The 1D model of the River Ouse and its two tributaries extend from Asselby Island on the River Ouse, Airmyn Butt on the River Aire and Decoy Farm on the Dutch River to Swinefleet on the River Ouse towards the Humber estuary. For each modelled reach, a constant inflow corresponding to the 50% annual probability (QMED) peak flow (estimated using FEH methods) was set at the upstream boundaries.

As the river system is tidally dominated within the study area, the downstream boundary was informed with a water level time series representing spring tide conditions plus a storm surge component associated with a 0.5% annual probability (200-1 annual chance) at Goole. As shown on Figure 1, under such conditions, the water level peaks at 5.76m AOD. The tidal information was provided by ABPmer Ltd.

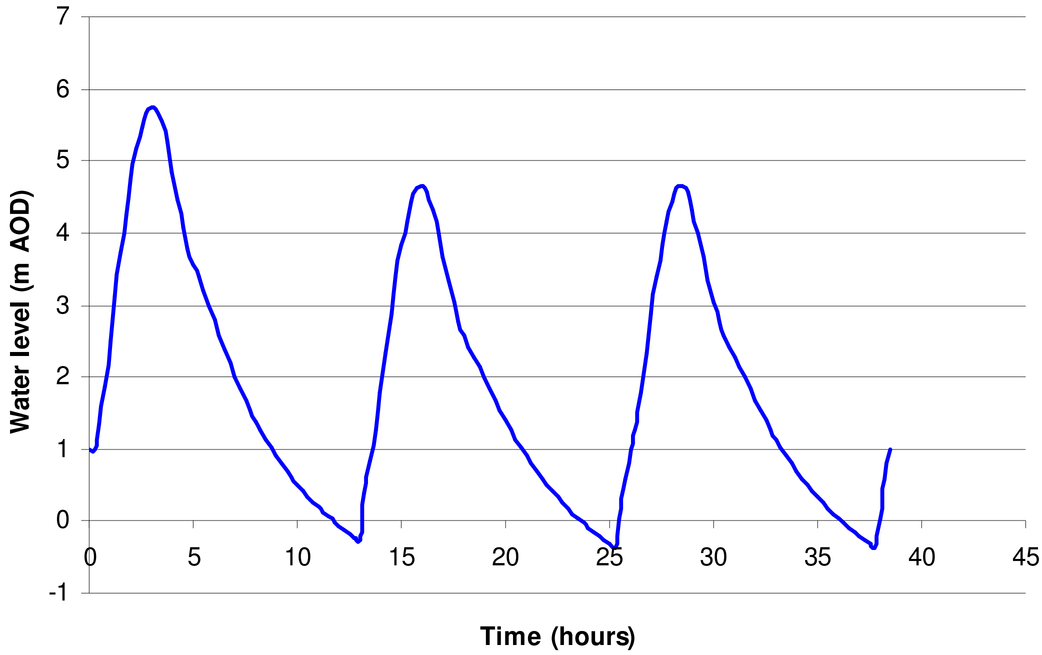


Figure 1: Tidally influenced downstream boundary conditions in the hydraulic model

3. Overview of the 2D model

The boundary extent of the 2D model representing the floodplain was centred on the Goole area. The 2D domain was based on a regular grid comprising individual square cells of a 10m side, as it was considered that this would provide adequate representation of the floodplain features – at least two to three grid cells across the major flow paths – whilst not becoming computationally cumbersome.

Each cell was given characteristics relating to the topography such as ground elevation, hydraulic resistance value and initial water level. Ground elevation information was extracted from low level filtered LiDAR data collected from the Environment Agency.

On either side of the modelled river reach, boundary lines were digitised along the raised defence crest lines to select 2D open flow boundary cells representing the dynamic links between the river system (1D domain) and the 2D domain. These allow flood water to spill to and from the 2D domain when the computed water level exceeds the bank crest elevation.

The 2D domain also includes a range of different hydraulic friction zones which alter the velocity and flow path depending on the land use (e.g.: buildings, roads, pasture).

Wherever appropriate the model grid was manipulated to ensure the accuracy the overland flow paths across the floodplain, in particular allowing flow under road bridges, through existing culverts within embankment.

4. Location & Configuration of Breaches

Ten specific breach locations in the flood defence line protecting Goole (right bank of the Ouse) were selected, which can be seen in Figure 2. Two methodologies were applied to generate the worse case scenario for extent and hazard. The first was to assume the breach occurred at t = 0, and was already in place before the flood event occurred, which meant a greater volume of water would pass through the breach and inundate the town. The second method assumed the breach would occur 3 hours into the simulation to coincide with the peak tidal level. This method would create the largest velocities due to the large difference between the maximum tidal level and ground level. The breach in this case was assumed to occur over 6 minutes.

In both methods, the width of the breach depended on the nature of the flood defence, which was set to 20m or 50m width for a hard and earth defence respectively. The bottom of the breach was assumed to be at the river berm level. The time it took for the breach to occur differed between the two methods. Table 1 details the width and breach level assumed for each breach.

Table 1: Breach details

Breach	Nature	Breach Width (m)	Breach Level (m AOD)
1	Earth defence	50	5.05
2	Hard defence	20	5.10
3	Hard defence	20	4.50
4	Earth defence	50	4.80
5	Hard defence	20	5.05
6	Earth defence	50	4.80
7	Earth defence	50	4.60
8	Earth defence	50	4.60
9	Earth defence	50	4.70
10	Hard defence	20	4.70

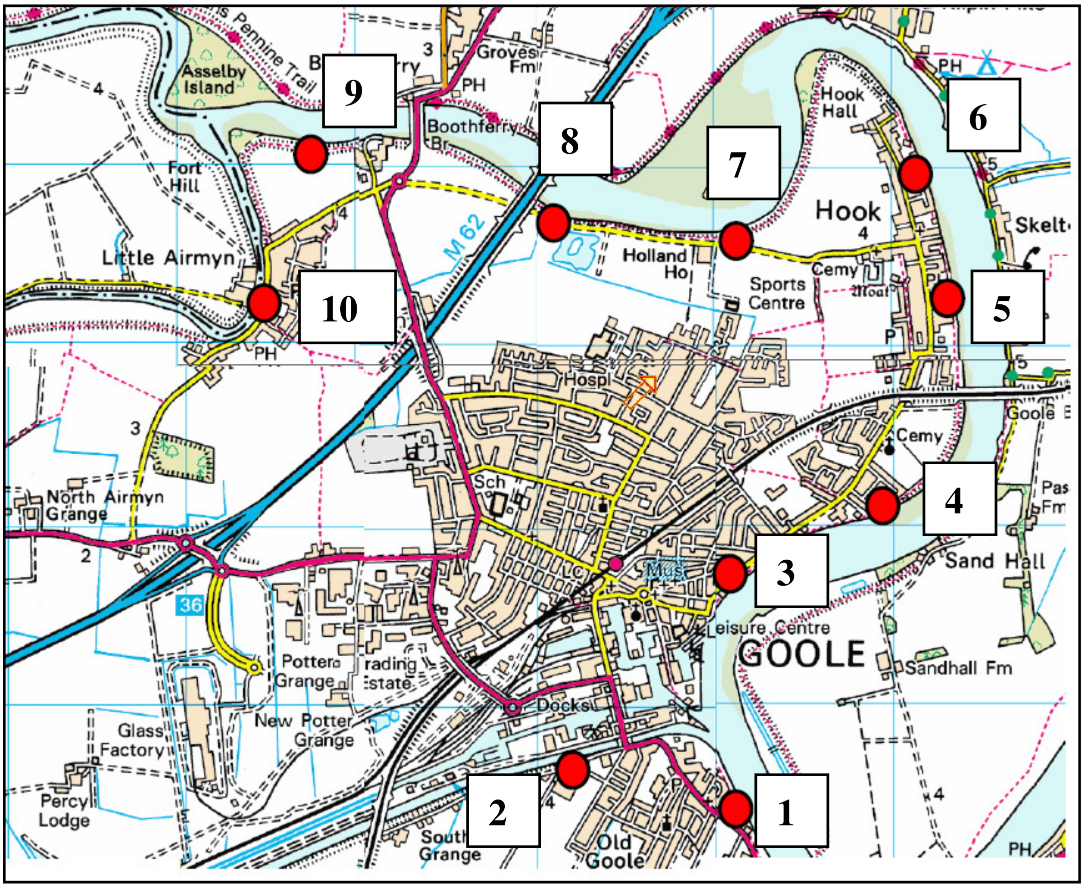


Figure 2: Breach locations

5. Model Runs

- *Defence Overtopping Runs*

To simulate overtopping of the defences from the river, the hydraulic model was run with all defences in place (existing situation) assuming 0.5% annual probability (200 -1 annual chance) tidal surge conditions in the river system.

An additional run was also considered to assess the effect of climate change (over a period of 100 years) on the above event. Considering the river regime is tidally dominated, a net water level rise of 1.03m (calculated following Defra guidance) was applied to the tidal cycle set at the downstream boundary of the 1D model.

- *Breach Modelling Runs*

The breach scenarios were run using the same 2D domain as the overtopping runs. Each of the 10 breach scenarios was run individually assuming 0.5% annual probability (200 -1 annual chance) tidal surge conditions in the river system. Although the duration of the flow across the breach would be limited to a couple of hours (as the tide rises and falls), the simulations were run for 50 hours to record the maximum extent of flooding across the very flat floodplain.

6. Flood Risk Mapping

For each scenario simulated, flood depth outputs were processed and converted into flood maps showing the maximum extent of flooding and the distribution across the modelled domain of the maximum flood depths recorded during each simulation.

Flood hazard was also computed by the hydraulic model and hazard zones were subsequently mapped according to Table 2 and Table 3 below.

Flood hazard was calculated as follows:

$$FH = D (V + 0.5) + DF$$

where, FH = flood hazard, D = flood depth, V = velocity, DF = debris factor

Table 2: Hazard to People as a Function of Velocity and Depth (Source: FD2320)

Flood Hazard	Degree of Flood Hazard	Description
< 0.75	Low	Caution
0.75 – 1.25	Moderate	Dangerous for some (children)
1.25 – 2.0	Significant	Dangerous for most people
> 2.0	Extreme	Dangerous for all

Table 3: Debris factors for different flood depths, velocities and dominant land uses (Source: FD2320)

Depths (m)	Conservative
0 to 0.25	0.5
0.25 to 0.75	1
d>0.75 and / or v>2	1

The debris factor has been calculated as a function of the flood depth within an urban environment, as set out in Table 3.

Combining the breach scenarios, a final map (Figure M) was also produced indicating the rate of ingress of the flood waters across the floodplain distributed by zones <6 hours, 6 to 12 hours, and >12 hours.

The final hazard maps were contoured so as to generate a complete hazard map for the entire Goole area. The methodology relies on the areas between the modelled breach locations being 'filled in' by using the modelled extents to interpolate the degree of hazard, influenced by interpreting the local topography. Land use was also taken into account in the assessment; for example, roads and watercourses tend to convey flood flows more efficiently than dense built up areas therefore high hazard was extended along major roads running away from the defences.

APPENDIX B
Figures