London Borough of Bexley

Strategic Flood Risk Assessment – Level 2

Final Report

October 2014










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Document revisions (

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3	Level 2 SFRA Final Report (incorporating EA comments)	December 2013
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London Borough of Bexley

Strategic Flood Risk Assessment – Level 2

October 2014

Entec UK Limited

Report for

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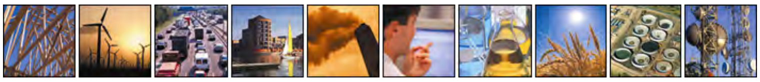

1. Introduction to the Level 2 SFRA

Entec has been appointed to undertake a Strategic Flood Risk Assessment (SFRA) Level 2 for London Borough of Bexley, (herein 'Bexley' or 'the Council'). Entec has worked with Bexley on a number of flood risk projects including, Level 1 SFRA, Erith Marshes Ditches and Dykes project, Crayford Town Centre SFRA, Howbury Site Flood Risk Assessment (FRA) and Erith Western Gateway FRA. Bexley procured a borough-wide assessment (Level 1), seeing this as an opportunity to build on the Council's existing level of flood risk knowledge and extend it to incorporate the whole borough, including those currently outside the Environment Agency's Flood Zones 2 and 3.

National planning legislation and policy guidance has been considered throughout the preparation of this SFRA. The planning process is driven by legislation and guidance developed at a national, regional and local level, of which flood risk is just one of many factors needing to be considered when making decisions relating to land use and development. The challenge for an SFRA is to develop pragmatic principles for steering future development towards areas of lower flood risk within the context of other planning policies and local drivers.

This Level 2 SFRA represents the second part of the borough wide assessment in Bexley. The Level 1 and Level 2 assessments undertaken in Bexley meet requirements set out in paragraph 100 of the Government's National Planning Policy Framework[1] and paragraph 7-8 of the Government's Technical Guidance to the National Planning Policy Framework (NPPF)[2].

This report should be read in conjunction with the Bexley Level 1 SFRA (August 2010). The Level 1 SFRA provides a comprehensive overview of relevant policy documents, borough-wide flood risks and general management of flood risk. The Level 2 SFRA applies to the sustainable growth areas set out in the Council's adopted local plan, the Bexley Core Strategy[3]. These areas are identified in Figure A1 in Appendix A.

Please note the flood levels quoted in this document were correct at the time of writing. More up to date information can be obtained from the Environment Agency.

1.1 Bexley's requirement for a Level 2 SFRA

The Technical Guidance to the NPPF advises that a Level 2 SFRA is required when either the Level 1 assessment does not provide sufficient detail to inform the application of the Sequential Test, or when there is development pressure within areas of identified flood risk, thus necessitating an increase in scope to provide the information for application of the Exception Test.

[1] Communities and Local Government, ***National Planning Policy Framework***, (March 2012).

[2] Communities and Local Government, ***Technical Guidance to the National Planning Policy Framework***, (March 2012).

[3] London Borough of Bexley, ***Bexley Core Strategy***, (February 2012).

The London Borough of Bexley Level 1 SFRA (August 2010) concluded that a Level 2 SFRA is required in certain parts of the borough due to the Council's need to propose development and regeneration within areas of identified flood risk. Much of the north and east of the borough is within the 'Thames Gateway Regeneration Area' and the 'Opportunity Areas' as defined by the London Plan; both of which place significant development and regeneration pressures on the local planning authority. The Level 1 SFRA (see Section 1.2) included a significant amount of detailed hydraulic modelling of the risks associated with a failure in the tidal flood defences. The Level 2 SFRA will take this information and that produced as part of the Crayford SFRA[4], the Erith Marshes Ditches and Dykes project[5] and the Thamesmead Canal Corridor Enhancement Master Plan[6]. The existing assessments of flood depth, hazard and rate of onset is sufficient to inform the Level 2 assessment and as such no further hydraulic modelling work has been undertaken. The Level 2 SFRA differs from the Level 1 SFRA in that the geographical scope of the assessment has shifted from borough wide to the six specific sustainable growth areas set out in Map 3.2 of the Bexley Core Strategy that fall wholly or partially within Flood Zone 3.

1.2 Purpose of the Level 2 SFRA

The Level 2 assessment will enable the sequential approach to be applied within the specific sustainable growth areas. Bexley propose to use the detailed outputs of the Level 2 and Level 1 SFRAs to inform production of planning policy documents. Therefore the Level 2 assessment will in particular, inform the site assessment process for the Bexley Detailed policies and sites local plan to ensure the delivery of homes and jobs, as set out in the Bexley Core Strategy. The Level 2 SFRA will also facilitate the application of a sequential approach to land use planning at the site specific level. Sites assessed in the Level 2 SFRA are sites identified through the Greater London Authority (GLA) strategic housing land availability assessment (SHLAA) (2009), which were approved following the application of the SHLAA methodology (see section 2.3), and the borough's designated employment areas as identified on the Council's adopted Unitary Development Plan proposals map.

The principal purpose of a Level 2 SFRA is to facilitate application of the Exception Test, as set out in the NPPF and the Technical Guidance to the NPPF, in all parts of the borough where it will need to be applied. The level 2 assessment will consider in detail the nature of the flood hazard. This will allow a sequential approach to site allocation to be adopted within a flood zone. It will establish practices required to ensure that development in such areas satisfies the requirements of the Exception Test. The Level-2 SFRA focuses on six of the nine Bexley Core Strategy sustainable growth areas, four of which are set within London Plan Opportunity Areas. These areas stretch across Bexley's northernmost wards adjacent the River Thames, from Thamesmead and Belvedere to Erith and Slade Green, and extend south along the borough's north-eastern boundary to Crayford and as such, have been earmarked both by the Government and Mayor of London as a priority for regeneration. The Level 2 SFRA provides the scope to refine the guidance to location specific flood risks.

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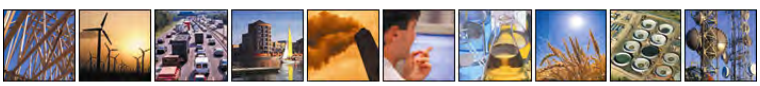
[4] Entec UK Ltd, ***London Borough of Bexley Crayford Town Centre SFRA*** (2007).

[5] Entec UK Ltd, ***London Borough of Bexley Erith Marshes Ditches and Dykes Study (Phase 1) Surface Water Management*** (2009).

[6] Entec UK Ltd, ***Environment Agency Thamesmead Canal Corridor Enhancement Master Plan – Evidence Base*** (2010).



1.3 Outcomes of the Level 1 SFRA

This section summaries the outcomes of the Level 1 SFRA and sets the context for the Level 2 assessment presented in this report.

The Level 1 assessment was designed to facilitate the application of the Sequential Test at the borough-wide scale. In addition to this, Bexley's Level 1 SFRA provides very detailed analysis of the residual tidal flood risks and presents guidance on safe development and development control guidance to support the application of the Exception Test at the site specific level.

The Level 1 SFRA is considered to be the most suitable tool to assist Bexley in the identification of sustainable growth locations at a borough-wide, strategic level. This process is being driven by the need to deliver the new homes, jobs, shops and associated infrastructure that is identified in the Bexley Core Strategy. Site specific locations within these sustainable growth areas will be set out in the Council's ***Detailed policies and sites local plan***, currently being prepared, which will include the reallocation of land uses. This will require Bexley, amongst other things, to determine which of their currently allocated employment sites should be released for other land-uses, including residential, and it is this work that the Level 2 SFRA supports.

The Level 1 SFRA assesses flood risk at the borough-wide scale. This includes the delineation of the Environment Agency's flood risk zones, an assessment of the implications of climate change, and the review of flood risks from all possible sources. The output of the detailed ISIS-TuFLOW modelling undertaken as part of the Crayford Town Centre SFRA has been incorporated. The Environment Agency Flood Zones has been supplemented with TuFLOW modelling of defence failure scenarios. This level of detailed hydraulic modelling is typically not included in Level 1 assessments and is more often only included as part of subsequent Level 2 work. In Bexley, the areas of flood risk were considered to be sufficiently extensive, that it was necessary to undertake additional modelling to inform the Level 1 assessment. This allowed for the Bexley Level 1 SFRA to include significant levels of area specific flood risk mitigation and management not normally associated with a Level 1 assessment.

The Level 2 SFRA provides additional detail to inform site allocations and changes to land use designations within the Bexley Core Strategy sustainable growth areas.

1.4 Geographical scope of the Level 2 SFRA – identification of the Bexley Core Strategy sustainable growth areas

The indicative sustainable growth areas are set out on Map 3.2 of the Bexley Core Strategy (2012), in a process which reviewed, amongst other things, the regeneration needs the local communities, economic development, the long term sustainability of the town centres and the deliverability of development and growth. The Bexley Core Strategy local plan provides full justification for the rationale behind the selection of the nine sustainable growth areas. This document was tested at an examination in public and found sound, and adopted by the Council in February 2012.

Of the nine sustainable growth areas identified in Figure A1 in Appendix A, Bexleyheath, Welling and Sidcup are not included in the Level 2 Assessment as they are located entirely within Flood Zone 1. For information relating to these areas and all other areas of Flood Zone 1, please consult the Level 1 SFRA (August 2010). This Level 2 SFRA is presented in seven main sections; a brief overview of each is outlined in Table 1.1.

Table 1.1 Level 2 SFRA overview

Section	Description
Section 1	Overview of the Level 1 SFRA, introduction to the Level 2 SFRA and scope of the Level 2 assessment
Section 2	Level 2 SFRA assessment approach
Section 3	Thamesmead and Abbey Wood and Belvedere sustainable growth areas
Section 4	Erith and Slade Green sustainable growth area
Section 5	Crayford sustainable growth area
Section 6	Old Bexley sustainable growth area
Section 7	Foots Cray sustainable growth area

For purposes of the Level 2 Assessment the two sustainable growth areas of 'Belvedere' and 'Thamesmead and Abbey Wood' have been combined as their respective flood risk conditions are very similar.

The sustainable growth areas are the only areas where Bexley will support residential development within Flood Zone 3 (where this 'more vulnerable use' as defined by the Technical Guidance to the NPPF would require the Exception Test), and therefore the only areas where Bexley will provide information to site specific FRAs to support the application of the Sequential Test and Part (a) of the Exception Test. However, for those potential development sites presented in the SFRA, and for windfall sites, which are either on the margins or partially within the indicative sustainable growth areas, the Council should be contacted for confirmation on whether the sustainable growth area status applies.

2. Level 2 SFRA – flood risk assessment methodology

2.1 Introduction

This section summarises the approach applied to assess flood risk in the Level 2 SFRA, the results of which are reported for each of the sustainable growth areas in Sections 3 to 7. As outlined in Section 1, the Level 2 Report should be read in conjunction with the Bexley Level 1 SFRA (August 2010) as this provides a significant level of detail describing the flood risk assessment methodology applied in the SFRA. This section does not include a discussion of the results. The reader is directed to Sections 3 to 7 for a discussion of results of the flood risk assessment and for guidance on the management of these risks.

For an overview on the sources of flooding assessed as being present in Bexley, the reader is directed to Section 2 of the Bexley Level 1 SFRA (August 2010).

2.2 Assessment methodology – sources of flood risk and hydraulic modelling

2.2.1 Residual tidal flood risk (infrastructure failure) assessment approach

The flood defences along the banks of the Thames protect the borough from direct tidal flooding. Residual flood risk is that element of the 'actual' flood risk which remains despite the presence of flood defences. In Bexley, the risk assessed relates to that risk which remains in the tidal floodplain despite the presence of the tidal flood defences. The tidal River Thames floodplain is divided into discrete flood cells. This SFRA refers to the flood cells as embayments. The embayments are topographic features that are comprised of low-lying areas separated by ridges of higher ground. Bexley has two such embayments; Thamesmead/Erith Marshes and Crayford Marsh (see Figure 8.1 in the Level 1 SFRA). The risks present in both of these are discussed respectively in Sections 3 and 4.

Detailed modelling of defence failure scenarios in the Thames defences was undertaken as part of the Level 1 SFRA. The assessment utilised the 2-dimensional modelling software TuFLOW. The Bexley SFRA modelling builds upon previous modelling undertaken for the Howbury Site Flood Risk Opportunities and Constraints Study (2008)[7], the Erith Western Gateway Appraisal of Master Plans (2008)[8] and the London Borough of Greenwich SFRA (October 2011)[9]. The results of the breach modelling, at a borough wide scale, are discussed in detail in

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[7] Entec UK Ltd, London Borough of Bexley, Erith Western Gateway Regeneration Scheme – Flood Risk Appraisal of Master Plans, (May 2008).

[8] Entec UK Ltd, London Borough of Bexley, Howbury Site Flood Risk Constraints and Opportunities Assessment, (April 2008).

[9] JBA and Entec UK Ltd, ***London Borough of Greenwich Strategic Flood Risk Assessment*** (October 2011).

Section 3 of the Bexley Level 1 SFRA (August 2010). The Level 1 SFRA Modelling Report has been reproduced in Appendix G of this report.

The TuFLOW approach allowed for maximum extents, depth, flood hazard, water surface elevation and time to onset of flooding to be predicted. The SFRA modelling utilises the 1 in 200 year tide level for the year 2107, which was the most distant climate change projection provided by the Environment Agency. In all the mapping produced as part of both the Level 1 and Level 2 SFRAs, the results from all the nine breach locations and the one over topping location are combined to form one potential maximum. The results of the individual models are not presented. This approach has been applied to ensure that the spatial planning process is guided by the worse possible case scenario. Due to the inherent nature of numerical modelling and the number of assumptions made, the results should be considered as estimations of peak flooding potential in the borough.

The TuFLOW modelling to establish the nature of the flood hazard is typically a Level 2 SFRA task. Nonetheless, it was undertaken as part of the Level 1 SFRA in Bexley as it was critical that the Council had a detailed appreciation of the risks in the tidal floodplain areas so as to inform the SHLAA process and the designation of the sustainable growth areas in the Bexley Core Strategy. The modelling approach was designed in such a way so as to ensure that the outputs would be suitable for use in the Level 2 SFRA, and as such, no further modelling work has been undertaken as part of the Level 2 assessment.

2.2.2 Areas of potential rapid inundation (unmodelled)

The resultant water levels in the embayments do not reach that of the 1 in 200 year tide level (plus climate change). This is because the water levels are a function of the volume of water that can pass through the breach in any given tidal cycle. The large volume of these embayments prevents the same level to be reached at both sides of the defence line, before the tide level starts to recede. Despite the large number of breaches modelled in this SFRA (10, including the data supplied by the London Borough of Greenwich SFRA), there are areas immediately behind the defences that were not shown to flood. These areas are not covered by the predicted extents associated with the simulated breaches. This is because the predicted flood extents associated with the breach modelling is product of the maximum water level that is achieved in the embayment, despite the land being lower than the 1 in 200 year tide level (plus climate change) in the River Thames.

These potential rapid inundation areas are considered to be potentially at risk should there be a breach at a location not simulated as part of the Level 1 SFRA. Figure 7 in Appendix A of the Level 1 SFRA identifies the ***'areas of potential rapid inundation (unmodelled)'.*** The SFRA recommends that development proposals in these areas should be accompanied by breach modelling analysis.

2.2.3 Fluvial flood risk – assessment methodology

Environment Agency fluvial flood zones 2 and 3 exist for the rivers Cray and Shuttle in Bexley. The flood zones on the River Shuttle extend upstream to the end of Hollyoak Wood Park at Days Lane Bridge. On the Wincham Stream (tributary of the River Shuttle) the flood zones extend as far upstream as where the B2214 (Halfway Street) crosses the watercourse. The flood zones on the River Cray extend all the way to the borough's boundary at the Sidcup Bypass (A20T). Figure A2 (in Appendix A) illustrates the extent of the Environment Agency flood zones 2 and 3 in Bexley and shows the combined extent of the fluvial and tidal zones.

2.2.4 Functional floodplain delineation

An area of functional floodplain has been defined in Crayford town centre. The designation extends from the tidal boundary upstream to the A2. The functional floodplain was defined as part of the Crayford Town Centre SFRA (2007)[10] by routing the 1 in 20 year fluvial flow through an ISIS-TuFLOW hydraulic model. However, the functional floodplain is not extensive in Crayford town centre. The main area is within a purpose built flood storage reservoir, located in the recreational grounds near Hall Place, upstream of the town centre. The reader is directed towards the Crayford Town Centre SFRA for further details of the detailed modelling and to Section 5 for a more detailed discussion of the risks within the sustainable growth area.

The Environment Agency carried out a remapping programme for the rivers Cray and Shuttle, which was completed in August 2010. As part of the modelling work, a 1 in 20 year fluvial scenario has been simulated along the length of the rivers Cray and Shuttle in Bexley. In addition to this, work carried out for an integrated urban drainage study for Crayford extended the modelling to include pluvial and sewer flooding.

Whilst this updated modelling supersedes the functional floodplain delineations presented in this SFRA, and should be utilised as part of any site specific flood risk assessments (FRAs) prepared to support proposed development, the fluvial flood risk information that informed the site allocation process within the sustainable growth areas is considered to be sufficient at a borough-wide, strategic level.

Environment Agency flood zone 3B – the functional floodplain, is defined in the Technical Guidance to the NPPF as comprising "land where water ***has*** to flow or be stored in times of flood." The guidance goes on to state that:

> "Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. But land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood in an extreme (0.1%) flood, should provide a starting point for consideration and discussion to identify the functional floodplain."

The NPPF technical guidance definition does not distinguish between land that is currently developed and land that is undeveloped, nor does the majority of floodplain modelling, as this typically assumes a 'bare earth' condition. A 'bare earth' condition is one where all existing development is removed from the ground model to allow for flood

[10] Entec UK Ltd, London Borough of Bexley, ***Crayford Town Centre SFRA***, (2007).

flow routes and ponding areas to be identified in the absence of buildings. Whilst there are obvious merits of this approach, it does not necessarily reflect the ***likely*** flood extents and flow routes. This is because in heavily urbanised floodplains, the presence of buildings can have a significant impact on the resultant flood extents.

Currently, developed areas of the 1 in 20 year flood extent should be classified as areas of Flood Zone 3a, as they are not considered functional parts of the floodplain, whereas areas of undeveloped land, usually designated as Metropolitan Green Belt or Metropolitan Open Land, and often identified as a site with importance to nature conservation, within the 1 in 20 year flood extent should be classified as Flood Zone 3b.

Development within Flood Zone 3a will require the Exception Test to be passed, which in some cases will be challenging, and in some cases not possible. The development of previously developed sites within this zone, within the sustainable growth areas, does however provide the potential for additional floodplain storage to be provided (in addition to that already available) by incorporating ‘space for water’ within the development design, where appropriate.

2.2.5 Surface water flood risk – assessment methodology

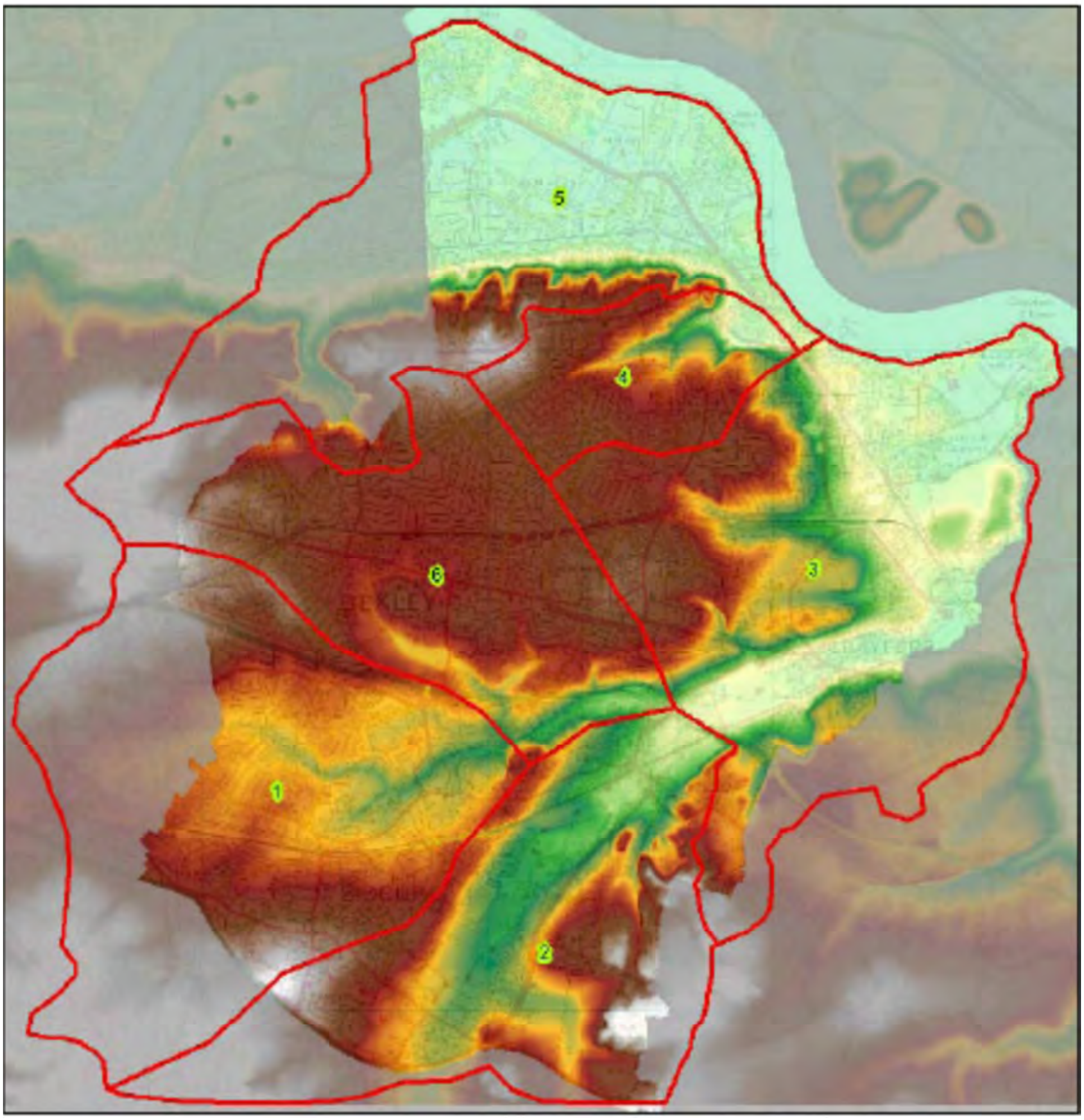
In preparing the Level-1 SFRA, the effect of an extreme rainfall event in Bexley was simulated to identify potential overland flow routes and ponding areas. The surface water modelling approach adopted is detailed in section 2.3.3 of the Bexley Level 1 SFRA (August 2010) and summarised below.

- The borough was subdivided into six hydrodynamically[11] distinct regions, which enabled a greater definition of the topography to be incorporated in the simulation. Figure 2.1 illustrates the six distinct areas;
- For each of the six areas (shown in Figure 2.1), the statistical 1 in 100 year plus climate change rainfall depth was calculated, using the FEH (Flood Estimation Handbook[12]) software and catchment descriptors. The FEH percentage runoff losses model was then used to evaluate what percentage of the rainfall may become runoff. Effective rainfall was then increased to account for the influence of climate change. The formalised piped drainage network was not considered in the estimations of rainfall, or in the subsequent surface runoff modelling as its capacity is unknown;
- The rainfall storms were then applied to the DTM (Digital Terrain Model[13]) surface within the hydraulic model TuFLOW. The modelling software routed the water over the digital terrain surface and highlighted potential flow routes and ponding areas for surface water.

[11] Hydrodynamically distinct = there is no route for water to flow between two areas. i.e. a watershed exists between two catchments
[12] Flood Estimation Handbook, Procedures for Flood Frequency Estimation, Institute of Hydrology 1999

[13] A Borough wide DTM based on 5m resolution SAR (Synthetic Aperture Radar) data from Infoterra was obtained for the SFRA for the purposes of generating surface water flooding predictions.

Figure 2.1 Illustration of the six surface water modelling catchments in Bexley



The modelling process used to map surface water risk in Bexley represents a significant simplification of reality, in that buildings are not represented, a uniform surface roughness is applied and the underground drainage network has been accounted for by removing the volume associated with the 1 in 30 year storm. Further, the assumption has been made that the surface water drainage network will manage the 1 in 30 year storm. These should be taken into consideration when interrogating the modelled results. The minimum depth presented is 0.2m. This reflects the purpose of the modelling, which was to identify potential areas of surface water flooding. Figures 18 and 19 (in Appendix A of the Level 1 SFRA) present the results of the surface water run-off modelling for the entire borough, and location specific mapping is provided in Appendices B to F of the Level 2 SFRA.

Bexley's drainage engineers were consulted for information on surface water and drainage flooding within the borough. Location specific mapping within Appendices B to F, illustrate the locations of recorded flooding events alongside the potential surface water flow routes and ponding areas. The points have been plotted using the six figure national grid references supplied by Bexley. These records have been compiled from observations made by Council officers and reports obtained from members of the public, and as such the potential inaccuracy of the data must be recognised.

2.2.6 Groundwater flood risk – assessment methodology

The Environment Agency provided a series of groundwater contours which represent predicted groundwater head at 10m intervals. Groundwater head is the theoretical level which would be recorded in a borehole, should one be sunk into the aquifer. The contours were produced by the Environment Agency, from maximum levels recorded and compiled in the late 1990s, and consequently do not include data relating to the exceptionally wet winter of 2000-2001 which resulted in high groundwater levels in the South East of England..

By definition, the groundwater head does not necessarily define the level below ground at which the water table sits. The water table is controlled by the nature of the surface deposits. In locations where there are thick layers of impermeable London Clay, the water table is suppressed below the groundwater head. This is because the clay prevents the water in the aquifer from rising towards the surface. Only where connectivity exists between the underlying aquifer and the surface (natural or manmade), will groundwater emerge at the surface.

As part of the SFRA process, the groundwater head contours were interpolated into a smooth surface within ArcGIS and then subtracted from the surface elevation. These calculations produced a grid of depth to groundwater head for the whole Borough (See Figure 8 in Appendix A of the Bexley Level 1 SFRA August 2010). Relevant area specific extracts are presented in Appendices B to F. The smaller values indicate where there is the potential for groundwater to be nearest the surface and thus the areas where there is the greatest potential for basement flooding.

The areas where the groundwater head is predicted to be nearest the surface are characterised by Chalk bedrock overlain by Quaternary deposits of alluvium, sands and gravels. These deposits, unlike the London Clay which caps the higher parts of Bexley, are not typically described as impermeable. The 1:50,000 geology mapping suggests that there is a potential route for groundwater to reach the surface. Groundwater flooding is therefore a potential risk along the valley bottom of the River Cray and River Shuttle, and in the Crayford Marshes and Thamesmead and Erith Marshes embayments.

All the low lying areas where the groundwater head is nearest the surface are capped with impermeable clays, so it is not predicted that there will be any significant issues arising from clear water flooding from the Chalk aquifer[14]. The other potential source of groundwater related flooding is where superficial sand and/or gravel deposits are perched on the clay strata. In these instances the local sand/gravel aquifer can become saturated during prolonged

[14] Clear Water Flooding being the action of groundwater rising to the surface and causing flooding.

intense rainfall and result in flooding at the surface. Any site specific FRAs should consider this potential risk through a review of local superficial and solid geology.

2.3 Assessment methodology – flood risk to SHLAA sites and employment land sites

The SHLAA (2009) sites in Bexley that have already been agreed with the GLA form the strategic housing sites that are the basis of Bexley's annual housing target set out in Table 3.1 of the London Plan 2011. The Environment Agency was involved in developing the methodology used to assess the sites in informing site constraints, such as biodiversity and flooding. Therefore, these sites are the ones that have passed the sequential test, as set out in the technical guidance to the NPPF, and any current planning applications are being assessed accordingly. The GLA is in the process of updating housing requirements for London boroughs in their Further Alterations to the London Plan, and a new SHLAA has been carried out to support this. Once adopted, Bexley will have a new housing target and the SHLAA (2013) sites in Bexley will also have passed the sequential test.

Bexley has an opportunity to reassess sites in its Detailed policies and sites local plan, for which the Level 2 SFRA will be one of the assessment tools, when, all employment land in the borough will be assessed. It is possible that some of the agreed SHLAA sites may no longer be appropriate for housing development if some of the employment land is designated for housing, and this means that the Council can meet its housing requirements. However, these changes will not form part of the borough's development plan until the Detailed policies and sites local plan is adopted with a policies map accompanying it illustrating the new land uses in the borough.

Where possible, sites outside zones of flood risk have been selected, but there are some instances where other community and sustainability drivers have required the selection of strategic housing sites or areas within a flood zone location. It is clear that flood risk has been a strong influencing factor in the site selection process, as of all the agreed SHLAA sites, only a small number are either entirely or partially within zones of flood risk. For the assessment of sites in the Detailed policies and sites local plan, in line with the sequential approach advocated by the NPPF, the less vulnerable employment land uses are being considered in the areas of higher flood risk, in preference to more vulnerable housing land uses.

The Level 2 SFRA has defined the distribution of different flood risk zones across each of the agreed SHLAA sites and designated employment areas. This process has utilised ArcGIS functionality, which allowed for each site or area to be divided based on the extent of the Environment Agency Flood Zones. Additionally, the Level 2 SFRA can be used as one of the tools to assess other sites put forward as part of the preparation of the Detailed policies and sites local plan.

2.4 Assessment methodology – infiltration potential

An infiltration potential map is provided for each of the sustainable growth areas discussed in Sections 3 to 7. This mapping represents a larger scale reproduction of that provided in Figure 12 of Appendix A of the Bexley Level 1

SFRA (August 2010). This mapping utilises the Environment Agency's groundwater vulnerability mapping and the Groundwater Source Protection Zone mapping. Infiltration potential is classified as, high, intermediate or low. These classifications are then further divided to inform developers as to whether the presence of a Source Protection Zone has an influence. Table 2.1 provides details of the classifications used.

Table 2.1 Classification Process Applied to Infiltration Suitability

Ground water vulnerability aquifer designation	Groundwater vulnerability soil classes	Presence of source protection zone	SFRA infiltration potential classification
Major	H3, HU, H1	No	High
Minor	H3, HU, H1		
Major	H3, HU, H1	Yes	High with caution
Minor	H3, HU, H1		
Major	I1	No	Intermediate
Minor	HU, H1, H3		
Major	I1	Yes	Intermediate with caution
Minor	HU, H1, H3		
Minor	I1	No	Low
Minor	I1	Yes	Low with caution*

*Classification not present in Bexley

Borough wide guidance on surface water management is provided in Section 7 of the Bexley Level 1 SFRA (August 2010). Where appropriate, elements of this guidance are repeated in the location specific sections in this Level 2 Report and are supplemented with location and site specific guidance.

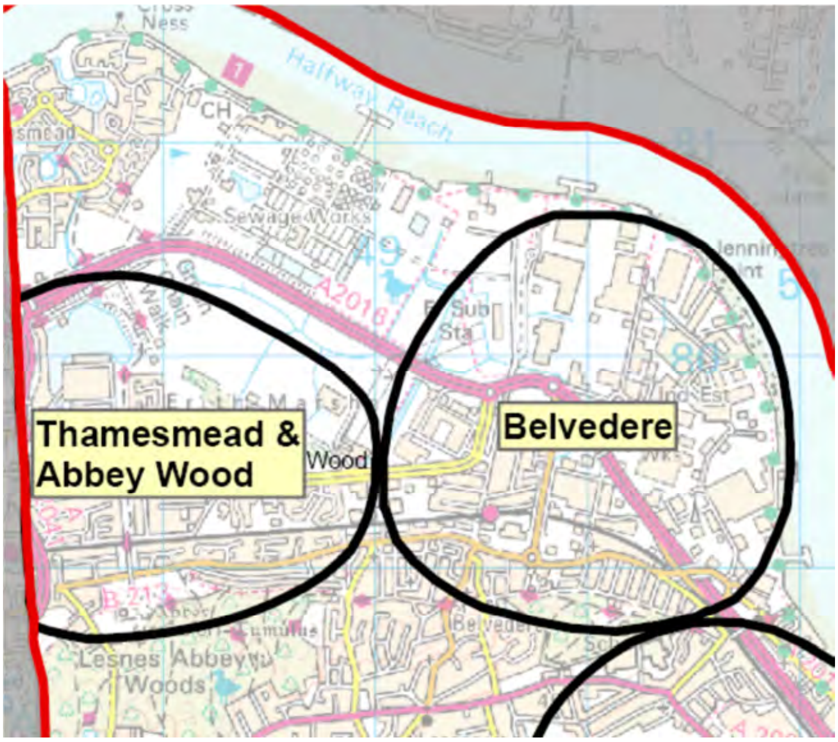
3. Thamesmead and Abbey Wood and Belvedere sustainable growth areas

This section is supported by the mapping provided in Appendix B.

3.1 Introduction

The Thamesmead and Abbey Wood and Belvedere sustainable growth areas are located in the north of the borough, with Thamesmead and Abbey Wood bordering the Royal London Borough of Greenwich to the west. Figure 3.1 illustrates the location of these areas. The physical characteristics, nature of the flood risks and recommended management responses are very similar for both these sustainable growth areas, which is why they are addressed together in the Level 2 SFRA.

Figure 3.1 Thamesmead and Abbey Wood and Belvedere sustainable growth areas (extract from figure A.1)



3.2 Assessment of flood risk

The three sources of flood risk in these two areas that the Level 2 SFRA will focus on are residual tidal flood risk, surface water flood risk and groundwater flood risk. Please consult Section 2 of this report for details of the assessment methodology applied.

3.2.1 Residual tidal flood risk

The areas covered in this section are located in what is known as the Thamesmead and Erith Marshes embayment. An embayment is the term used to describe an area of floodplain which is topographically distinct from other parts of the floodplain due to areas of higher land which extend right down to the river. In the case of the Thamesmead and Erith Marshes embayment, the topographic high points are Woolwich Arsenal in the west and Erith in the east. The southern boundary is defined by ground levels, but generally the southern boundary follows the North Kent Railway line.

Predicted tidal flood depth and peak flood water level

Predicted flood depths are significant within the Thamesmead and Erith Marshes embayment, with most flooded areas exceeding 2m (Figure B3 in Appendix B), although the depth of flooding is highly dependant on variations in the local topography.

In the Thamesmead and Abbey Wood and Belvedere sustainable growth areas, maximum peak flood water levels reach approximately 4.4m AOD (above ordnance datum, or above sea level). Following the adoption of the Thames Estuary 2100 (TE2100) plan (November 20112), the Environment Agency is now providing extreme water levels in the Tideway based on the TE2100 modelling.

Predicted tidal flood hazard

Flood hazard across the embayment is high, with most areas having a hazard classification of 'hazard to all' as defined by ***Flood Risk to People***[15] and illustrated in Figure B4 (in Appendix B). Hazard is defined as a function of the depth and velocity of flood water plus a debris factor.

TuFLOW uses the following hazard equation which is defined in the FD2321/TR1[16] Report.

$$D*(V + 0.5) + DF$$

Where: D = Depth, V = Velocity, 0.5 = a constant to provide a conservative estimate, DF = Debris Factor which is variable according to depth.

In the Thamesmead and Erith Marshes embayment depth is the most influential factor on the classification. The exceptions to this are in the immediate vicinities of the breach location, or where moving water becomes bottlenecked. In these cases velocities have the greatest impact on hazard categorisation. Flow bottlenecks are noted along Erith's West Street, and along Church Manorway.

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[15] Defra/Environment Agency (2006). ***Flood Risk to People***, FD2321/TR2, Guidance Document.

[16] Defra/Environment Agency (2006). ***Flood Risk to People***, FD2321/TR2, Guidance Document.

Predicted rate of tidal flooding onset

Figure B6 in Appendix B illustrates the predicted durations from the point of defence failure to the onset of flooding at a particular location. The map represents a composite of results from all nine breach models and one over topping model. This indicative mapping is included so as to add further differentiation to the nature of the flood risk to inform the spatial planning process and not for the purpose of informing emergency plans. A range of factors have the potential to alter the time to onset of flooding at any give location, these include amongst other parameters: the location of the breach; the width of the breach; the point in the tidal cycle at which the breach occurs; and the surface roughness.

Nevertheless the modelling predicts that the Belvedere sustainable growth area is likely to be flooded more quickly (less than 3 hours from point of breach) than the Thamesmead and Abbey Wood sustainable growth area, which is predicted to take between 3 and 6 hours to flood. Thus in the event of a flood those living in Thamesmead and Abbey Wood should potentially have a longer window of time for evacuation.

3.2.2 Surface water flood risk

Existing assessments

This part of the borough benefits from a large modelling study undertaken by Entec in 2009/2010 for Bexley, the two parts are outlined below:

- London Borough of Bexley, The Erith Marshes Ditches and Dykes Modelling Study, Phase 1 (December 2009);
- London Borough of Bexley, The Erith Marshes Ditches and Dykes Modelling Study, Phase 2 (February 2010).

The Thamesmead part of the area (i.e. around Southmere Lake and the approach to Abbey Wood railway station around Wolvercote Road and Lensbury Road) is covered by a similar project also undertaken by Entec (2010) for the Environment Agency. The report reference is given below

- Environment Agency, The Thamesmead Canal Corridor Enhancement Master Plan – Modelling Evidence Base (May 2010).

For a full account of the predicted flood risks and the modelling work undertaken, the reader is directed towards the reports referenced above. Please contact Regeneration, Major Projects, or Structure and Drainage Teams at the London Borough of Bexley for details on how the Erith Marshes reports can be obtained. The Thamesmead Canal Corridor Enhancement Master Plan and associated technical evidence bases can be requested from the Environment Agency through the External Relations department.

Both these detailed modelling studies included the construction of fully integrated Info Works CS models of the surface water sewer networks that contribute flows to the Erith Marshes (i.e. the Marsh Dykes catchment) and to the Thamesmead canal and lake system. In the case of the Thamesmead system, this involved modelling the Wickham Valley Watercourse catchment, which flows northwards through the Royal Borough of Greenwich. The Marsh Dykes catchment is dominant in both sustainable growth areas, with only small parts of the Thamesmead and Abbey Wood sustainable growth area being included within the Thamesmead canal system.

Surface water flood risks

The modelling work undertaken in 2009 and 2010 illustrated that there were a number of local capacity issues in the surface water sewer network that caused localised flooding. The nature of the flooding mechanisms is not straightforward, owing to the complexity of the system and all the component parts, which includes piped surface water drains, connections under the railway line, small ditches, wide canals, lakes, large culverts and pumping stations. The majority of the flooding was predicted to occur in the areas served by the Thames Water sewers as a result.

The performance of much of the network that drains into the Yarnton Way culvert is limited, under storm conditions, by the water level in ditches and dykes. The Yarnton Way culvert collects water from the Abbey Wood area and discharges it into the southern end of Great Breach Dyke; this structure is classified as an Environment Agency Main River and it runs parallel to the north side of the railway line. The current managed water level in the ditches and dykes is -0.76m AOD, which is very close to the soffit (roof of the culvert), and this results in there being little surplus capacity in the Yarton Way culvert to respond to storm flows.

Other flooding hotspots are historically around Belvedere railway station and Mitchell Close. The issues in the area around the railway station are associated with the rapid change in gradient at the bottom of the hill, where the steep piped catchment discharges into a small ditch to the rear of the B&Q superstore, resulting in flooding along Station Approach. In Mitchell Close the reported issues are associated with surcharged water flowing from manholes around the junction between Mitchell Close and Lower Road. The flooding is not reported to be originating from the Mitchell Close ditch, but rather it is associated with there not being a well defined flow route for surface water to drain into the ditch.

The Thamesmead Canal Corridor modelling project (May 2010) predicted that even during extreme rainfall events (1 in 100yr +CC), Southmere Lake was not assessed as presenting a flood risk to the surrounding residential areas. The modelling did however predict surcharging issues from Thames Water surface water sewers in the Wolvercote Road and Lensbury Road areas. The surface water flooding in these areas was identified as being sensitive to the lake levels in Southmere. When lake levels become elevated, the resultant surcharging of the contributing drains exacerbates the surface water flooding predictions.

3.2.3 Groundwater flood risk

The potential for groundwater emerging at the surface and causing localised flooding issues is highlighted in Figure B8 in Appendix B and described in Section 3.2.3 of the Level 1 SFRA. Within Thamesmead and Abbey Wood and Belvedere, the base geology is chalk, which is known to be a major aquifer. Only in the very north of the Belvedere Employment Area is this chalk capped with impermeable deposits of London Clay. For the majority of the Erith Marshes, the underlying geology is not considered to present a hydraulic barrier to the rise of groundwater from chalk aquifer. As such there is the potential for groundwater levels to rise to near the surface and in the lowest areas emerge at the surface. The mapping presented in Figure B8 presents a representation of groundwater levels for the winter of 2001, based upon 10m groundwater levels issued by the Environment Agency. This mapping indicates that risk of groundwater levels being near or at the surface during prolonged wet periods is potentially high in the topographically low areas. The results presented in Figure B8 are indicative as they do not account for the role of the rivers Cray (located to the east), Shuttle (located to the south) and Thames (located to the north), which receive discharge from the groundwater.

The risk of groundwater flooding is however considered to be locally variable as the composition and stratigraphy of the overlying superficial deposits will influence how groundwater levels in the chalk aquifer will translated into groundwater levels within the superficial deposits.

Nevertheless, the Erith Ditches and Dykes modelling studies concluded that there is likely to be groundwater present in the superficial deposits above the London Clay strata, related to the managed water levels in the ditches and dykes. The risk of basement flooding as a result of ground water intrusion is assessed as potentially high. Site specific assessments should assess this potential risk in detail.

3.3 Management of flood risk – through avoidance

The flood risk management guidance presented for the Thamesmead and Erith Marshes Embayment remains aligned with that published in Section 8 of the 2010 Level 1 SFRA and should be consulted alongside this Level 2 SFRA.

3.3.1 Site allocations

Within Thamesmead and Abbey Wood and Belvedere sustainable growth areas, the majority of the sites identified in this SFRA are currently designated as Primary Employment Land in Bexley's adopted Unitary Development Plan (UDP), see Figures B1and B2 in Appendix B. This is with the exception of three large potential housing sites north of the railway and two small sites to the south. In line with the NPPF and its technical guidance, 'Less Vulnerable' land uses like employment are compatible with a Flood Zone 3a location. The guidance does not require the Exception Test to be passed for 'Less Vulnerable' land uses in Flood Zone 3a. Bexley's approach to placing the least vulnerable land uses in this potentially high flood risk area is in line with the ethos and objectives of the sequential approach to land use planning. The SFRA recommends that flood risk management measures

should be applied to ‘Less Vulnerable’ land uses, despite the Exception Test not being necessary, as the FRAs to support these developments must still demonstrate that the proposed development is safe.

All the SHLAA sites illustrated on Figure B1 in Appendix B are located within Flood Zone 3. This is a defended floodplain and as such the sites are in a zone of residual risk. The breach modelling undertaken as part of the Level 1 SFRA (1 in 200 year event in the year 2107) predicts that all the sites are at risk of flooding in the event of a failure in the tidal Thames flood defences (see Figures B3, B4 and B5 in Appendix B). The three large sites, located respectively adjacent to Harrow Manor Way, Kale Road and Picardy Manor Way are all in areas assessed as having a flood hazard rating of ‘Danger for All’ (FD2321) and with depths exceeding 3m.

Based on the Level 1 SFRA modelling the Picardy Manor Way site could be flooded within 3 hours of a breach and the other two sites are predicted to be flooded in less than 6 hours. The two smaller sites that are located south of the railway line are within Flood Zone 3a, but are on the edge of the zone of risk associated with a defence failure. Along the southern boundary of both sites, it is predicted that the hazard rating will reduce from ‘Dangerous to All’ to ‘Dangerous to Most’. In the same way, flood depths along the southern boundary of both sites are predicted to be less than 2m. On this basis, the two smaller sites, at the edge of the zone of residual risk, are assessed as being in slightly lower risk areas than the larger sites.

3.3.2 Onsite land use planning

Applying the sequential approach to risk avoidance onsite is a management approach that should be deployed when there is a differentiation of risk zones across the site. For the three larger sites, the flood risk is consistently high, with little or no differentiation in flood hazard and only small variations in depth. As such, a sequential risk based approach to land use planning on these sites will not deliver significant risk reductions. For these sites, management through design (Section 3.4) will be necessary.

For the smaller sites adjacent to the southern boundary of the residual flood risk zone, there is a differential in the flood hazard rating and this should inform the layout of buildings on these sites. For example, the building configuration should be designed to ensure that no one unit is isolated within the zone of greatest flood hazard, this could be achieved through inter-building connections or small amounts of landscaping. Moreover entrance and exit routes should be orientated so that there people can move intuitively from the areas of higher hazard to lower hazard during a flood event.

3.4 Management of flood risk – through design

3.4.1 Building design

Residential and ‘more vulnerable’ land uses

The finished floor levels of more vulnerable uses should be above the predicted maximum water level resulting from a breach in the defences during the 1 in 200 year plus climate change tidal event. This figure represents a composite maximum water surface level of all the Bexley SFRA breaches and the Royal Greenwich SFRA (October 2011) breach models. Please note that there may be more up to date predicted maximum water level information and anyone considering proposals for development should contact the Council and the Environment Agency.

The NPPF and its technical guidance do not distinguish between room uses in stating a flood risk vulnerability classification for any one type of development, but in the case of residual risk it is reasonable to take into account both the detailed nature of flood hazard and consequence of flooding in looking at building design. For example the consequence of garages flooding will be less than that of bedrooms. However, the NPPF technical guidance does recognise, in note c to table 2 (flood risk vulnerability classification), that the impact of a flood on the uses within a vulnerability classification will vary within each vulnerability class.

Providing that room use with a low consequence from flooding can be reasonably assured in perpetuity, then relaxations to the 1 in 200 year plus climate change requirement may apply. In perpetuity assurance could be achieved through a planning condition and a restriction on permitted development within a building footprint. An example of such a relaxation would be allowing residential uses (which fall into the ‘more vulnerable’ classification) below flood levels, **provided that they are not bedrooms, or any other living spaces that could be converted into bedrooms**.

Flood-free evacuation to dry land is only possible for sites on the edge of the residual flood risk zone. For those sites where development is anticipated to be surrounded by flood waters, the only means of safe escape is internally upwards. If safe escape routes to areas outside the floodplain are not feasible, new developments should be designed to incorporate internal safe space where occupants can congregate and seek refuge in and/or be rescued from in the event of a breach. This refuge should meet the following requirements:

- Be an easily accessible space protected from the elements above the predicted maximum flood level;
- Be large enough to protect the number of occupants the building is anticipated to contain (could be more than one place of refuge in a building);
- Include space for provisions to be stored for emergencies (e.g. fresh drinking water, torch, radio); and
- Be designed so as to allow the people taking refuge to be able to let rescuers know that they are there (e.g. a window large enough from which people can hail for rescue and escape).

New developments should be designed to incorporate both internal and where possible external space where occupants can congregate and seek refuge in and/or be rescued from in the event of a breach. Where possible, new builds should be designed to allow for easy rescue by boats, such as from low level windows or balconies.

Employment and ‘less vulnerable’ land uses – where safe escape cannot be provided.

For ‘Less Vulnerable’ uses, for example employment, it is appropriate for the ground floor level to be set below the predicted 1 in 200 year (plus climate change) peak flood level. Nevertheless, the developers should be mindful of the potential consequences that several metres of flood water will have on their units, and attention should focus on the business continuity risks associated with flood damage. Where feasible all new industrial developments should include either a second storey or mezzanine floor space, sufficient in size to provide refuge for all those who will work within the building. The mezzanine/second storey floor level should be set above the 1 in 200 year plus climate change peak flood level. This measure is important because of the potentially rapid speeds of flooding onset in the event of a failure.

The time to flooding, presented in Figure B6 in Appendix B, assumes that the breach exists at the start of the tidal cycle. It is probable however, that a failure in the defences would occur at the highest point in the tidal cycle, which would result in significantly shorter time to flooding onset. Industrial developments should also consider the means by which the building will be evacuated, for example, by ensuring that there is access to roof areas for aerial rescue or to windows and balconies above the peak water level for rescue by boat.

3.4.2 Basements

It is recommended that habitable rooms in basements should not be permitted in Flood Zones 2 or 3. Adaptation of existing properties to include a basement for habitable rooms, or to create a habitable space from an existing non-habitable basement, should be discouraged in Flood Zones 2 and 3. It is however recognised that the implementation of this may be challenging, as basement development is sometimes classified as Permitted Development when within the bounds of the existing building. In this case, educating the public as to the dangers of adding or adapting basement space would be a possible approach.

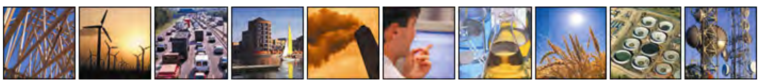
Basements for less vulnerable uses or non habitable rooms must be designed with safe internal escape. Site specific analysis should accompany any proposal, to demonstrate that a proposed basement would not impact the flow of groundwater in such a way that the risk of groundwater flooding elsewhere is increased, and to demonstrate that the basement will not be flooded by locally high groundwater levels.

Basements in the Thamesmead and Erith Marshes Embayments should be avoided.

3.4.3 Resilience and resistance measures

Where predicted flood depths exceed 0.6m

Building resilience in the Thamesmead and Erith Marshes Embayment is a fundamental aspect to any development scheme. Buildings must retain structural integrity in the event of a flood. Flood depths in parts of the embayment have been estimated to exceed 3m. It is thought that standard masonry buildings are at significant risk of structural damage if there is a water level difference between the outside and the inside of the building is in excess of 0.6m. Water entry strategies are favoured in these situations which promote flood resilience rather than flood resistance.



The 'Improving the Flood Performance of New Buildings[17]' report should be consulted for flood resilience design guidance. A summary of mitigation measures that should be considered at the detailed design stage for developments where the flood depths are expected to exceed 0.6m are:

- Accept water passage through building at higher water depths;
- Attempt to keep water out for low depths of flooding;
- Use materials with a low permeability at lower levels;
- Provide key services including electricity, water etc. to continue under flood conditions;
- Site electrical controls, cables and appliances above the predicted maximum flood levels;
- Design to drain water away after flooding;
- Ensure access to all spaces to permit drying and cleaning.

The impact the flood waters will have on the structural integrity of the buildings must be considered at the detailed design stage. It must be demonstrated that the buildings will remain safe in the event of a breach in the flood defences during a high tidal event.

Where predicted flood depths are less than 0.6m – from surface water flooding

Within the Thamesmead and Erith Marshes embayment, particularly within the Marsh Dykes catchment, there is risk of localised flooding from the ditches and dykes network. This risk is associated with extreme rainfall events exceeding the capacity of the ditches and dykes. The Environment Agency and Bexley have been working on projects to reduce the flood risk posed by the ditches and dykes network, and a new pumping station has been installed by the Environment Agency at the downstream end of Green Level Dyke. Nevertheless, there is a potential risk to new development adjacent to the ditches and dykes. Owing to the ongoing works and alterations, it is not possible to use the results of the 2009 Erith Marshes Ditches and Dykes Study to define an absolute maximum flood level. This risk is considered to be associated with damages to ground floor uses rather than a risk to people. For details on predicted flood depths and extents developers are encouraged to request peak water levels, depth data and flood extent maps from the London Borough of Bexley. The SFRA recommends the installation of flood exclusion strategies to manage this source of flooding. Options might include:

- Slight raising of the ground floor slab level (please consult the Phase 2 Erith Marshes Study, on request from Bexley);
- Water exclusion strategies, such as placing flood gates across doorways and raising air bricks;
- Using building materials and equipment on the ground floor that are resilient to water damage;
- Raising electric sockets and other utilities above the predicted flood levels (please consult the Phase 2 Erith Marshes Study, on request from Bexley).

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[17] Improving the Flood Performance of New Buildings – Flood Resilient Construction, Communities and Local Government, 2007.

3.5 Management of flood risk – through emergency response

For those larger SHLAA sites within the zone of potential residual flood risk, it is not going to be possible to provide safe access and egress throughout the duration of a flood event. This situation is a product of the distances to the edge of the residual flood risk zone, the predicted depths and associated flood hazards.

The Environment Agency will provide technical advice and support, but the decision as to whether a development proposal is 'safe' remains with the Local Planning Authority. In the case of the Thamesmead and Erith Marsh Embayments, it could be argued that the safest option is to provide safe, appropriate and intuitive refuge within the development (see the requirements set out in section 3.4.1, above), rather than attempting to undertake wholesale evacuation during a flood event. Please note that the SFRA makes this point in relation to residual tidal flood risk only; alternative guidance is provided for those areas at risk of fluvial flooding.

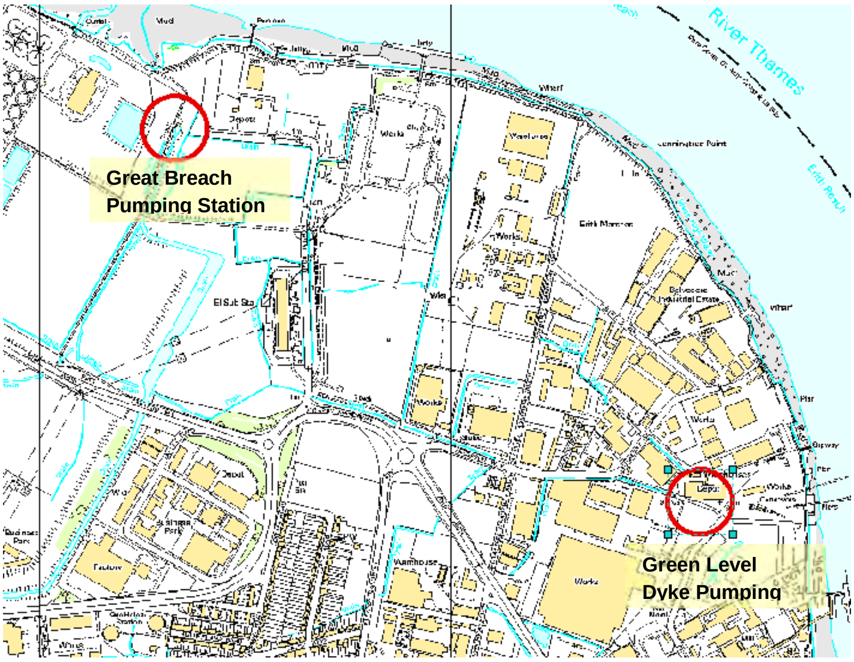
3.6 Surface water management

All surface water from the Belvedere Employment Area and along Yarnton Way drains into the network of open watercourses known as the Erith Ditches and Dykes. This drainage infrastructure extends across the area illustrated in Figure 3.2. From the Ditches and Dykes water is either discharged under gravity at low tide, along the culvert at Great Breach Pumping Station, or pumped from one or both of the pumping stations identified on Figure 3.2. The managed water level in the ditches and dykes is controlled by the crest level of a series of stop logs at Great Breach pumping station. This water level control structure maintains a water level of -0.76mAOD[18] during normal conditions. The ponded water level may fall during prolonged dry periods and it rises during periods of heavy rainfall.

In the east of the area, in Thamesmead and Abbey Wood, surface water is drained into the Thamesmead Canal network. This water body comprises both canal features and lakes which are all interconnected. Surface water is conveyed from the residential areas towards the gravity outfall at Abbey Sluice which is in the north east corner of Thamesmead adjacent to Crossway Lake. If tide levels are high and the gravity outfall is closed then storm water is discharged from the canal and lake system to the River Thames by Lake 4 pumping station which is situated in Lake 4 to the north of Thamesmead town centre.

[18] As surveyed in 2009.

Figure 3.2 Locations of Great Breach and Green Level Pumping Stations in Erith Marshes



In all cases drainage schemes prepared to support development proposals should provide storage for the 1 in 100+CC (climate change) critical storm.

The discharge rates from all sites should not allow unrestricted discharge rates for all storm events up to the 1 in 100 year +CC rate of discharge. It is recommended that the drainage strategy prepared for proposed development sites includes a review of greenfield and current discharge rates for storm events ranging from the 1 in 2 year to the 1 in 100 year storm including an allowance for climate change.

In order that flood risks are not increased, run-off rates for development should be managed to greenfield rates, which are defined as the runoff rates from a site, in its natural state, prior to any development. The only exceptions to this, where greater discharge rates may be acceptable, are where a pumped discharge would be required to meet the standards or where surface water drainage is to tidal waters and therefore would be able to discharge at unrestricted rates.

The drainage scheme proposed for the development should then either be to set the allowable discharge rate to the mean annual flood for all storms up to the 1 in 100-year+CC critical duration event, or have a variable discharge rate designed to mimic the relative increases in discharge that occur from an undeveloped site, in response to different storm probabilities. This can be achieved through the installation of hydro-brakes. The rationale for this is so that discharge from the site, post development, closely matches the current pattern of discharge.

The range of storms should be agreed with the Environment Agency, and both the Environment Agency and Thames Water should be consulted if the discharge is to the piped network, rather than directly to the ditches,

dykes or canals. Direct discharge should be agreed with the Environment Agency and Bexley's Drainage Team in advance, and the proposed drainage scheme should include measures to ensure that contaminants from the site are not discharged into the river system.

Measures to provide attenuation in the Thamesmead and Erith Marshes embayment include:

- Infiltration is not considered to be a viable option owing to the nature of the substrate and the potentially high groundwater level. A site specific infiltration test will be required to demonstrate the effectiveness of infiltration;
- Where possible the use of green roofs and rainwater harvesting should be utilised;
- Creation of attenuation ponds and/or wetland areas. The potential for ground contamination from previous or proposed industrial processes should be considered as part of the design process;
- Extension of the ditch and dyke network. It is essential that this option is discussed with the Environment Agency and Bexley's Drainage Engineers as adaptation and extension of the ditches and dykes can only be considered if proposals do not compromise the performance of the system and are not constrained by current infrastructure. Only additional storage above the managed water level of -0.76mAOD constitutes storage;
- As with all options, discharge rates should be controlled, which could be achieved either through the use of attenuation and hydro-breaks on site, or through the use of control structures in the ditches and dykes to separate the 'extension' from the rest of the network. The latter options must be discussed in detail with the Environment Agency;
- Underground storm cells or oversized pipes. These measures should be viewed as the least preferred option as they offer no wider (ecological, water quality or amenity) values. Their use should be supported by a demonstration that other more sustainable options are not technically feasible.

Further guidance on the selection of SuDS techniques is provided in the Level 1 SFRA (2010).

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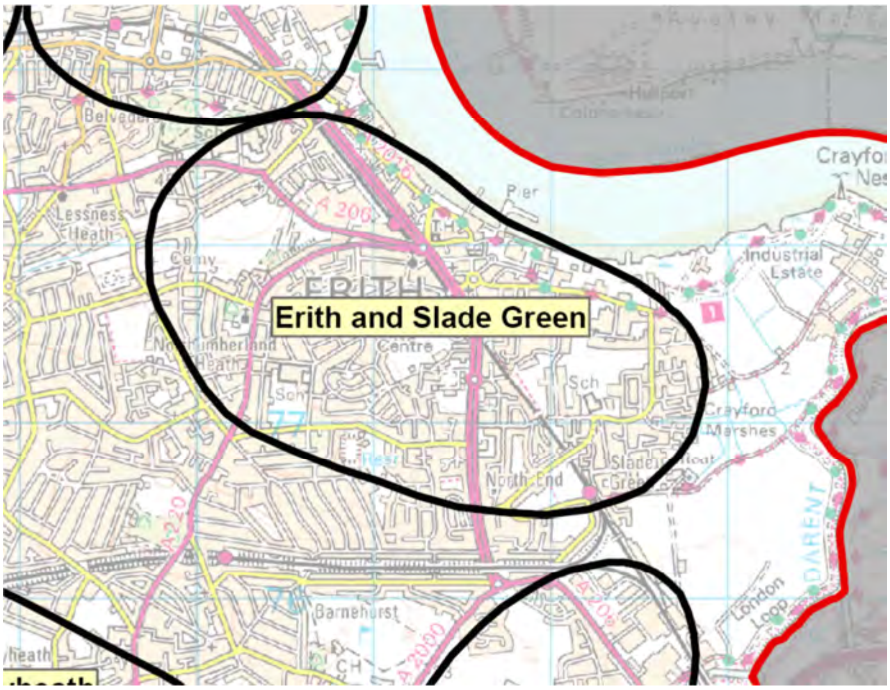
4. Erith and Slade Green sustainable growth area

This section is supported by the mapping provided in Appendix C

4.1 Introduction

The Erith and Slade Green sustainable growth area is located in the north east of the Borough, and includes parts of Northumberland Heath and North End. Figure 4.1 illustrates the location of this area.

Figure 4.1 Erith and Slade Green Sustainable Growth Area



Extract from Figure A1 in Appendix A

4.2 Assessment of flood risk

The three sources of flood risk in this area that the Level 2 SFRA will focus on are: residual tidal flood risk, surface water flood risk and groundwater flood risk. Please consult Section 2 of this report for details of the assessment methodology applied.

4.2.1 Residual tidal flood risk

The Environment Agency Flood map indicates that parts of the eastern, western and northern portions of this sustainable growth area are in zones of flood risk, although most of this area is located in the high land that divides two flood embayments. To the west of the area is the Thamesmead and Erith Marshes Embayment. To the east of the area is what is referred to in the Level 1 SFRA as the Crayford Marsh Embayment. This large, topographically low area, of which only a small part is located within the Erith and Slade Green sustainable growth area, is bounded to the west and south by the higher land of Erith and Slade Green, and by the River Darent tidal defences to the east. To the east of the River Darent, the low lying embayment extends across north Dartford. The tidal floodplain in London is currently defended against extreme tide levels up to and including the 1 in 1000 year level. Thus the zones of flood risk in this area are classified as 'residual' as this is a defended floodplain only at risk of flooding if the defences were breached or overtopped.

The Level 1 SFRA assessed the residual risk to this part of the Borough by simulating a number of breach scenarios and an overtopping scenario along the length of the River Darent tidal flood defences (assuming that the Darent flood gate was not closed). The results from these modelled scenarios have been combined to produce a composite flood risk map, illustrating the potential worst case from all the modelled scenarios. If alternative scenarios were run, the results may be different.

Predicted tidal flood depth and peak flood water level

The extent of the residual risk area is for the most part very similar to the current Environment Agency Flood Zone extents, despite the different modelling methods applied. It must be noted that the Flood Zones represent present day predictions whereas the breach modelling/residual risk analysis is applying tide levels inclusive of 100 years of climate change induced sea level rise.

To the east of Slade Green, in the Crayford Marsh Embayment, the flood depths are predicted to exceed 3m, whereas in Erith depths are not predicted to much exceed 1.5 to 2m (see Figure C3 in Appendix C). Only small pockets of deeper flooding are predicted, for example to the rear of the former swimming pool site in the Erith Western Gateway.

Peak flood water levels in this area are more varied than in the Thamesmead and Abbey Wood and Belvedere sustainable growth areas; this is a product of there being a greater variation in the local topography. The area along Garden Wharf (to the east of Erith Pier) towards Anchor Bay (located in the middle of the Manor Road Industrial Area) is the topographically highest part of the floodplain and the high peak water levels in this area are the product of the breach which was simulated along this reach, rather than from water flooding in from Erith Marsh or Crayford Marsh. Figure C5 in Appendix C illustrates predicted peak flood water levels in this area.

Predicted tidal flood hazard

Flood hazard in the Erith and Slade Green sustainable growth area is the embayment is varied, although much of the area is located within Flood Zone 1. However, some parts, particularly to the northwest of Erith town centre and in Slade Green, are classified as 'Dangerous to Most' as defined by ***Flood Risk to People***[19] and as illustrated in Figure C4 (in Appendix C). Hazard is defined as a function of the depth and velocity of flood water plus a debris factor.

TuFLOW uses the following hazard equation which is defined in the FD2321/TR1 Report.

$$D*(V+0.5)+DF$$

Where: D = Depth, V = Velocity, 0.5 = a constant to provide a conservative estimate, DF = Debris Factor which is variable according to depth.

In the Crayford Marsh Embayment, depth is likely to be the most influential factor on the classification. The exceptions to this are in the immediate vicinities of the breach location, or where moving water becomes bottlenecked. In these cases velocities have the greatest impact on hazard categorisation. A potential flow bottleneck is identified along Erith's West Street and under the railway bridge leading in to the Europa Trading Estate, just to the east of the Thamesmead and Erith Marshes Embayment.

Predicted rate of tidal flooding onset

Figure C6 in Appendix C illustrates the predicted durations from the point of defence failure to the onset of flooding at a particular location. The map represents a composite of results from all nine breach models and one overtopping model. This indicative mapping is included so as to add further differentiation to the nature of the flood risk to inform the spatial planning process and not for the purpose of informing emergency plans. A range of factors have the potential to alter the time to onset of flooding at any give location, these include amongst other parameters: the location of the breach; the width of the breach; the point in the tidal cycle at which the breach occurs; and the surface roughness.

Taking the modelling assumptions into account, it is still clear that some areas are predicted to take longer to flood than others. This differentiation is more a product of ground elevation rather then proximity to the breach location, with higher ground typically taking the longest to flood. Within the Erith and Slade Green sustainable growth area, this dataset (Figure C6 in Appendix C) provides a useful tool to differentiate flood risk within the same floodplain. To this end, all the SHLAA sites have at least part of their boundary within an area outside the zone of residual risk and the majority of the employment sites are at least partially within areas that are predicted to take over 15 hours to flood.

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[19] Defra/Environment Agency (2006). ***Flood Risk to People***, FD2321/TR2, Guidance Document.

4.2.2 Surface water flood risk

There are a couple of reported incidents of highway flooding in Slade Green, and the area at the north end of Walnut Tree Road in Erith is known to suffer from surface water flooding. These areas do not benefit from a detailed surface water flooding study and as such the flooding mechanisms must be assumed. In Slade Green the reported incidents are likely to be associated with either blockages in the drainage network or localised capacity issues. At the north end of Walnut Tree Road it is likely that tide locking of the drainage outfalls is a significant factor.

Figure C7 illustrates the results of the surface water modelling undertaken as part of the Level 1 SFRA. Included on this mapping are a series of reported flooding incidents which were collated by the Council and issued to Entec in August 2010. There do not appear to be significant areas of predicted surface water flood risk, or incidents of reported flooding issues within any of the SHLAA or employment sites. There are however locations, like along Avenue Road, where there is a potential surface water flow route and reported incidents are coincident. The other potentially significant area, although outside of the sustainable growth area, is along Eversley Road adjacent to the railway line embankment.

4.2.3 Groundwater flood risk

The potential for groundwater emerging at the surface and causing localised flooding issues is highlighted in Figure C8 in Appendix C and described in Section 3.2.3 of the Level 1 SFRA. Within the Erith and Slade Green sustainable growth area, the base geology is chalk, which is a major aquifer, and the geology mapping does not indicate the presence of a capping layer of impermeable London Clay. As such there is the potential for groundwater levels to rise to near the surface and in the lowest areas (e.g. the Crayford Marsh) emerge at the surface. The mapping presented in Figure C8 presents a representation of groundwater levels for the winter of 2001, based upon 10m groundwater levels issued by the Environment Agency. This mapping indicates that risk of groundwater levels being near or at the surface during prolonged wet periods is potentially high in the topographically low areas. The results presented in Figure C8 are indicative as they do not account for the role of the rivers Cray (located to the east) and Thames (located to the north), which receive discharge from the groundwater.

The risk of groundwater flooding is however considered to be locally variable as the composition and stratigraphy of the overlying superficial deposits will influence how groundwater levels in the chalk aquifer will translated into groundwater levels within the superficial deposits.

4.3 Management of flood risk – through avoidance

4.3.1 Site allocations

The SHLAA selection process and the employment land review have clearly involved the application of a sequential risk based approach to the avoidance of flood risk. For in this sustainable growth area, the sites at greatest risk are currently in employment use, whereas the SHLAA sites are all either in Flood Zone 1, or only partially within the zone of residual risk and thus providing the potential for safe access and egress to be facilitated. This is with the exception of three sites, these being:

- The small site to the east of James Watt Way along Garden Reach of the Thames;
- The small site to the north west of Ocean Park along the Thames frontage;
- The site adjacent to Bonzeage Way near St Fidelis Road.

These three SHLAA site are entirely within the zone of residual risk, with the latter two sites being assessed as being in areas of significant flood hazard, and with the first site listed is in an area of lower flood hazard. On this basis, it is recommended that these three sites are not used for residential land uses if at all possible.

4.3.2 Onsite land use planning

Applying the sequential approach to risk avoidance onsite is a management approach that should be deployed when there is a differentiation of risk zones across the site. If there are to be a number of different land use types proposed for a site, then the vulnerability should be matched to the predicted flood risks. Not only does this reduce the risk to people, it also reduces the need for engineering solutions to manage flood risk.

Wherever possible, site layout for all land uses should be steered by the principle of being able to secure safe access and egress for all occupants during the entire duration of a flood event. This can be achieved either through linking buildings together or through targeted manipulation of ground levels. The escape routes should be intuitive and this is best achieved if they are the same routes used by people on a daily basis.

For the Manor Road Industrial Area, a large employment area to the east of the Morrison's superstore and to the north of the Howbury site, safe escape will be more challenging. One option might be to route people through the adjacent Howbury site to the south, Or alternatively, the 'likely rate of inundation' map (Figure C6 in Appendix C) could be used to inform the design of safe escape routes by placing access/egress roads and paths along the areas predicted to take more than 15 hours to flood. Please note the modelling assumptions that are applied to this data in the Level 1 SFRA modelling methodology appendix.

4.4 Management of flood risk – through design

This guidance remains consistent with that outlined for the Thamesmead and Abbey Wood and Belvedere sustainable growth areas, with the main difference being that in the Erith and Slade Green area there is a greater opportunity for facilitating safe escape through well designed site layout, which should be implemented.

4.4.1 Building design

Residential and 'more vulnerable' land uses

The finished floor levels of more vulnerable uses should be above the predicted maximum water level resulting from a breach in the defences during the 1 in 200 year plus climate change tidal event. This data should be derived from Figure C5 in Appendix C. This figure represents a composite maximum water surface level of all the Bexley SFRA breaches and the Royal Greenwich SFRA (October 2011) breach models. Please note that there may be more up to date predicted maximum water level information and anyone considering proposals for development should contact the Council and the Environment Agency.

The NPPF and its technical guidance do not distinguish between room uses in stating a flood risk vulnerability classification for any one type of development, but in the case of residual risk it is reasonable to take into account both the detailed nature of flood hazard and consequence of flooding in looking at building design. For example the consequence of garages flooding will be less than that of bedrooms. However, the NPPF technical guidance does recognise, in note c to table 2 (flood risk vulnerability classification), that the impact of a flood on the uses within a vulnerability classification will vary within each vulnerability class.

Providing that room use with a low consequence from flooding can be reasonably assured in perpetuity, then relaxations to the 1 in 200 year plus climate change requirement may apply. In perpetuity assurance could be achieved through a planning condition and a restriction on permitted development within a building footprint. An example of such a relaxation would be allowing residential uses (which fall into the 'more vulnerable' classification) below flood levels, **provided that they are not bedrooms, or any other living spaces that could be converted into bedrooms**.

Flood-free evacuation to dry land is only possible for sites on the edge of the residual flood risk zone. For those sites where development is anticipated to be surrounded by flood waters, the only means of safe escape is internally upwards. If safe escape routes to areas outside the floodplain are not feasible, new developments should be designed to incorporate internal safe space where occupants can congregate and seek refuge in and/or be rescued from in the event of a breach. This refuge should meet the following requirements:

- Be an easily accessible space protected from the elements above the predicted maximum flood level;
- Be large enough to protect the number of occupants the building is anticipated to contain (could be more than one place of refuge in a building);
- Include space for provisions to be stored for emergencies (e.g. fresh drinking water, torch, radio); and

- Be designed so as to allow the people taking refuge to be able to let rescuers know that they are there (e.g. a window large enough from which people can hail for rescue and escape).

Employment and less vulnerable land uses

For 'Less Vulnerable' uses, for example employment, it is appropriate for the ground floor level to be set below the predicted 1 in 200 year (plus climate change) peak flood level. Nevertheless, the developers should be mindful of the potential consequences that several metres of flood water will have on their units, and attention should focus on the business continuity risks associated with flood damage.

In the Erith and Slade Green sustainable growth area, safe escape is the preferred flood risk management option. However, it is considered necessary for less vulnerable developments (e.g. employment) to include the provision of a second storey or mezzanine floor above the peak 1 in 200 year flood level (plus climate change) if it is not possible to facilitate safe escape. If this is the case, industrial developments should also consider the means by which the building will be evacuated, for example, by ensuring that there is access to roof areas for aerial rescue or to windows and balconies above the peak water level for rescue by boat.

The Europa Trading Estate area is almost completely detached from the wider zone of flood risk, other than through the railway underpass. The SFRA modelling assumed ground levels under the bridge based on LiDAR and dimensions were estimated from OS mapping, a more detailed site specific FRA might consider evaluating these assumptions. The SFRA base DTM was set at a 10m resolution which was suitable for large scale mapping. A site specific FRA might consider using a finer resolution DTM to define the extent of flooding in this area.

4.4.2 Basements

It is recommended that habitable rooms in basements should not be permitted in Flood Zones 2 or 3. Adaptation of existing properties, to include a basement for habitable rooms, or to create a habitable space from an existing non-habitable basement, should be discouraged in Flood Zones 2 and 3. It is however recognised that the implementation of this may be challenging, as basement development is sometimes classified as Permitted Development when within the bounds of the existing building. In this case, educating the public as to the dangers of adapting basement space would be a possible approach.

Basements for less vulnerable uses or non habitable rooms must be designed with safe internal escape. Site specific analysis should accompany any proposal, to demonstrate that a proposed basement would not impact the flow of groundwater in such a way that the risk of groundwater flooding elsewhere is increased, and to demonstrate that the basement will not be flooded by locally high groundwater levels.

Basements in flood zones 2 and 3 of the Erith and Slade Green sustainable growth area should be avoided.

4.4.3 Resilience and resistance measures

Where predicted flood depths exceed 0.6m

Building resilience is a fundamental aspect to any development scheme. Buildings must retain structural integrity in the event of a flood. Flood depths in parts of the embayment have been estimated to exceed 3m. It is thought that standard masonry buildings are at significant risk of structural damage if there is a water level difference between the outside and the inside of the building is in excess of 0.6m. Water entry strategies are favoured in these situations, which promote flood resilience rather than flood resistance.

The 'Improving the Flood Performance of New Buildings[20]' report should be consulted for flood resilience design guidance. A summary of mitigation measures that should be considered at the detailed design stage for developments where the flood depths are expected to exceed 0.6m are:

- Accept water passage through building at higher water depths;
- Attempt to keep water out for low depths of flooding;
- Use materials with a low permeability at lower levels;
- Provide key services including electricity, water etc. to continue under flood conditions;
- Site electrical controls, cables and appliances above the predicted maximum flood levels;
- Design to drain water away after flooding;
- Ensure access to all spaces to permit drying and cleaning.

The impact the flood waters will have on the structural integrity of the buildings must be considered at the detailed design stage. It must be demonstrated that the buildings will remain safe in the event of a breach in the flood defences during a high tidal event.

Where predicted flood depths are less than 0.6m – from surface water flooding

For details on predicted flood depths and extents developers are encouraged to request peak water levels, depth data and flood extent maps from the London Borough of Bexley. The SFRA recommends the installation of flood exclusion strategies to manage this source of flooding. Options might include:

- Slight raising of the ground floor slab level (please consult the Phase 2 Erith Marshes Study, on request from Bexley);
- Water exclusion strategies, such as placing flood gates across doorways and raising air bricks;
- Using building materials and equipment on the ground floor that are resilient to water damage;

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[20] Improving the Flood Performance of New Buildings – Flood Resilient Construction, Communities and Local Government, 2007.

- Raising electric sockets and other utilities above the predicted flood levels (please consult the Phase 2 Erith Marshes Study, on request from Bexley).

4.5 Management of flood risk – through emergency response

The Environment Agency will provide technical advice and support, but the decision as to whether a development proposal is ‘safe’ remains with the Local Planning Authority. In the case of the Erith and Slade Green sustainable growth area, evacuation in the event of a flood should be considered as a primary flood risk management measure. To achieve this, it is recommended that the supporting FRAs demonstrate the routes to be used and the locations where refuge will be sought. An emergency plan such as this will need to be approved by the Bexley’s Emergency Planning Officer.

The building design requirements outlined in Section 4.4.1 remain in place despite the provision of safe escape routes, as the building design manages the risk associated with an individual not understanding the emergency procedure or for some reason not being unable to leave a building.

4.6 Surface water management

The Erith and Slade Green sustainable growth area is not in Groundwater Source Protection Zones (SPZ) 1 or 2, although a small area is in SPZ3, and the western part of this area has been assessed as having an intermediate potential for infiltration and the eastern portion has been assessed as having a high potential. Infiltration as a means of managing storm water run-off should be seen as the primary option. Site specific investigations should include infiltration tests and consideration of ground contamination, especially as this area has a history of industrial use, and local groundwater levels.

The piped drainage network has a finite capacity (not assumed to be more than the 1 in 30 year storm). As such it is important that any new development provides sufficient on site storage to attenuate surface water run-off from each site for events up to and including the 1 in 100 year plus climate change event. This is to ensure that any new development does not increase the risk of flooding elsewhere. Furthermore, it is highly likely that Thames Water will insist upon discharge rates not increasing above the current discharge rate.

In all cases drainage schemes prepared to support development proposals should provide storage for the 1 in 100 year+CC climate change critical storm.

The discharge rates from all sites should not allow unrestricted discharge rates for all storm events up to the 1 in 100 year +CC rate of discharge. It is recommended that the drainage strategy prepared for proposed development sites includes a review of greenfield and current discharge rates for storm events ranging from the 1 in 2 year to the 1 in 100 year storm including an allowance for climate change.

In order that flood risks are not increased, run-off rates for development should be managed to greenfield rates, which are defined as the runoff rates from a site, in its natural state, prior to any development. The only exceptions to this, where greater discharge rates may be acceptable, are where a pumped discharge would be required to meet the standards or where surface water drainage is to tidal waters and therefore would be able to discharge at unrestricted rates.

The drainage scheme proposed for the development should then either be to set the allowable discharge rate to the mean annual flood for all storms up to the 1 in 100-year+CC critical duration event, or have a variable discharge rate designed to mimic the relative increases in discharge that occur from an undeveloped site, in response to different storm probabilities. This can be achieved through the installation of hydro-brakes. The rationale for this is so that discharge from the site, post development, closely matches the current pattern of discharge.

The range of storms should be agreed with the Environment Agency, and both the Environment Agency and Thames Water should be consulted if the discharge is to the piped network, rather than directly to the ditches, dykes or canals. Direct discharge should be agreed with the Environment Agency and Bexley's Drainage Team in advance, and the proposed drainage scheme should include measures to ensure that contaminants from the site are not discharged into the river system.

Measures to provide attenuation in the Erith and Slade Green sustainable growth area include:

- Infiltration from filter strips, French drains, swales and attenuation basins A site specific infiltration test will be required to demonstrate the effectiveness of infiltration and an assessment of groundwater conditions and land contamination issues;
- Where possible the use of green roofs and rainwater harvesting should be utilised;
- Creation of attenuation ponds and/or wetland areas;
- Using the topography to create linked SuDS features and thus increase the opportunity for ecological and public realm enhancements;
- Underground storm cells or oversized pipes. These measures should be viewed as the least preferred option as they offer no wider (ecological, water quality or amenity) values. Their use should be supported by a demonstration that other more sustainable options are not technically feasible.

Further guidance on the selection of SuDS techniques is provided in the Level 1 SFRA (2010).

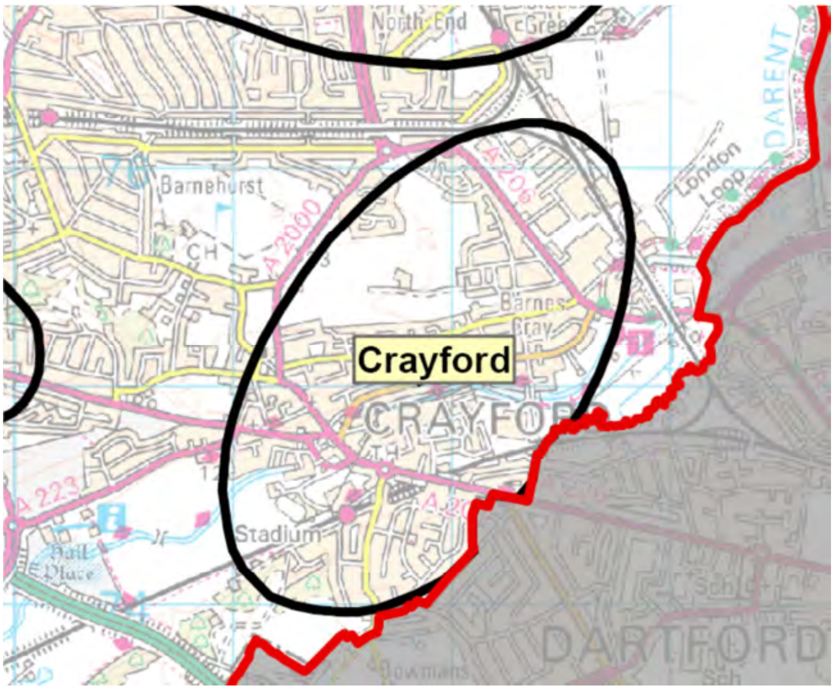
5. Crayford sustainable growth area

This section is supported by the mapping provided in Appendix D.

5.1 Introduction

The Crayford sustainable growth area, focused on Crayford town centre, the Tower Retail Park, the Crayford Industrial Area and the Thames Road Industrial Area, is located in the east of the borough adjacent to the borough boundary with Dartford. Figure 5.1 illustrates the location of this area. The flood risks and flood risk management guidance in the Crayford sustainable growth area is very similar to those in both the Old Bexley and Foots Cray sustainable growth areas, and should be considered together, thus allowing for the development of a consistent 'River Cray Corridor' approach to be adopted for land use planning and development control.

Figure 5.1 Crayford sustainable growth area



Extract from Figure A1 in Appendix A

5.2 Assessment of flood risk

The four sources of flood risk in this area that the Level 2 SFRA will focus on are: residual tidal flood risk, fluvial flood risk, surface water flood risk and groundwater flood risk. Please consult Section 2 of this report for details of the assessment methodology applied.

Within the Crayford sustainable growth area, there are locations that are predicted to be at risk from both residual tidal and fluvial sources. These two sources are independent of one another and the resultant flooding predictions have not been combined. The respective significance of each source is location dependant. As such the reader is advised to consult all Figures in Appendix D, so as to ensure that the most significant source of flooding is accounted for when making spatial planning decisions or informing building layout and design.

5.2.1 Residual tidal flood risk

The Environment Agency flood map indicates that there is a continual flood risk zone running through the town centre (associated with the River Cray) and into Crayford Marsh, right up to the tidal Thames defences. The flood zones to the north east of the sustainable growth area are attributed by the Environment Agency as being fluvial/tidal, which indicates that there is a flood risk to the north east of the area, associated with the tide. As with all other parts of the tidal floodplain in Bexley, this is a defended floodplain, indeed it is a continuation of the Crayford Marsh embayment which is described in Section 4.2.1. As such, the tidal flood risk in the Crayford sustainable growth area is classified as residual risk, as tidal flooding will only occur if the tidal defences fail or are overtopped.

The Level 1 SFRA assessed the residual risk to this part of the borough by simulating a number of breach scenarios and an overtopping scenario along the length of the River Darent tidal flood defences (assuming that the Darent flood gate was not closed). The results from these modelled scenarios have been combined to produce a composite flood risk map, illustrating the potential worst case from all the modelled scenarios. If alternative scenarios were run, the results may be different.

The results of the residual tidal flooding in the Crayford sustainable growth area are potentially sensitive to the way in which the underpasses under the railway embankment, which runs from Slade Green to Dartford, are represented in the TuFLOW model. If at a later stage the model is adapted and updated with surveyed information, then the resultant flooding predictions may vary. For the purposes of informing strategic level land use planning decisions, the SFRA modelling is sufficient.

Predicted tidal flood depth and peak flood water level

The extent of the residual risk area is for the most part very similar to the current Environment Agency Flood Zone extents, despite the different modelling methods applied. It must be noted that the Flood Zones represent present day predictions whereas the breach modelling/residual risk analysis is applying tide levels inclusive of 100 years of climate change induced sea level rise.

Figures D3, D4 and D5 in Appendix D, illustrate the predicted extent of the residual tidal flood risk in the Crayford sustainable growth area, associated with the simulated defence failure scenarios during the 1 in 200 year event (plus climate change allowance). The flood waters are predicted to exceed 3m deep in the marshland areas to the east of the growth area adjacent to the Dartford borough boundary, although this is outside the growth area boundary. Flooding is predicted to occur in and around the railway sidings and adjacent workshops to the south east of Slade

Green railway station, which is again outside of the growth area boundary. In Crayford town centre, the residual tidal flooding extends up the River Cray floodplain, almost as far as the A2000 crossing. Flooding in the Tower Retail Park and Crayford Industrial Area is predicted to be in the order of between 0.5m and 1m deep with peak flood water elevations in the order of 4.41- to 4.89mAOD. Please note that in this part of the sustainable growth area there is also a fluvial flood risk element (see Section 5.1.2).

Predicted tidal flood hazard

Flood hazard in the sustainable growth area is varied, with a small part being classified as 'Dangerous to Most' as defined by ***Flood Risk to People***[21] and as illustrated in Figure D4 (in Appendix D). Hazard is defined as a function of the depth and velocity of flood water plus a debris factor.

TuFLOW uses the following hazard equation which is defined in the FD2321/TR1 Report.

$$D*(V+0.5)+DF$$

Where: D = Depth, V = Velocity, 0.5 = a constant to provide a conservative estimate, DF = Debris Factor which is variable according to depth.

In the Crayford sustainable growth area, in the small area that has been identified as having a tidal flood hazard, the predominant hazard classification associated with residual tidal flood risk is 'Dangerous for Most.'

Predicted rate of tidal flooding onset

Figure D6 in Appendix D illustrates the predicted durations from the point of defence failure to the onset of flooding at a particular location. The map represents a composite of results from all nine breach models and one overtopping model (although in this location only breaches which flood the Crayford Marsh affect the Crayford sustainable growth area). This indicative mapping is included so as to add further differentiation to the nature of the flood risk to inform the spatial planning process and not for the purpose of informing emergency plans. A range of factors have the potential to alter the time to onset of flooding at any given location. These include, amongst other parameters: the location of the breach; the width of the breach; the point in the tidal cycle at which the breach occurs; and the surface roughness.

Taking the modelling assumptions into account, it is still clear that some areas are predicted to take longer to flood than others. This differentiation is more a product of ground elevation rather then proximity to the breach location, with higher ground typically taking the longest to flood. The modelling undertaken indicates that the part of the Crayford sustainable growth area that is as risk of tidal flooding is predicted to take over 15 hours to flood.

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[21] Defra/Environment Agency (2006). ***Flood Risk to People***, FD2321/TR2, Guidance Document.

5.2.2 Fluvial flood risk

The fluvial flood risk information presented in this Level 2 SFRA is based upon ISIS-TuFLOW modelling that was undertaken as part of the Crayford Town Centre SFRA (2007). This modelling provides an indication of the likely flood risks, but it will be shortly superseded by revised modelling undertaken along the rivers Cray and Shuttle by the Environment Agency. However, the Level 2 SFRA has been completed using the data available from the start of the study, although it is recognised that it will soon be superseded. **The reader is advised to consult section 2.2.4 of this report for details on the Functional Floodplain delineation in Bexley.**

Fluvial flood risk predictions, based on the Crayford Town Centre SFRA (2007), are presented in Figures D7, D8 and D9 of Appendix D.

Predicted fluvial flood depths and peak water levels

Within the Crayford sustainable growth area SHLAA sites, flood depths are predicted to be generally less than 0.75m, and within the employment areas, flood depths are predicted to be up to 1m, during the 1 in 100 year (plus climate change) event, as illustrated by Figure D7. Peak water levels associated with this simulated flood event range from 3m to over 6.5m AOD (see Figure D9). This large variation is a product of the down valley slope through Crayford.

The Environment Agency should be consulted as part of any site specific assessment and the latest river model predictions should be requested.

Predicted fluvial flood hazard

There is predicted to be a range in flood hazards throughout the fluvial floodplain that runs through the Crayford sustainable growth area, as illustrated by Figure D8. Of parts of the Tower Retail Park and Crayford Industrial Area, located just east of the town centre, the majority of the fluvial flood risk is classified as being ‘Dangerous for Most’. Only a small portion at the southeastern end of the Thames Road Industrial Area is predicted to be at risk of from fluvial flooding and the hazard rating here is predicted to be ‘ Dangerous for Most’ on the south side of the railway, and a mix of ‘Caution’ and Dangerous for Most’ to the north.

Upstream of the A2000 crossing, where the majority of the SHLAA sites and the secondary employment land are located, the fluvial flood hazard prediction includes all classifications, with the exception of ‘Dangerous for All.’ The areas of higher hazard rating correspond to the areas of deeper flooding.

5.2.3 Surface water flood risk

Figure D10 illustrates the results of the surface water modelling undertaken as part of the Level 1 SFRA, included on this mapping are a series of reported flooding incidents which were collated by the Council and issued to Entec in August 2010.

A significant potential surface water flow route is predicted to be present across the north of the sustainable growth area, through Perry Street Farm and down Mayplace Avenue, before draining into the River Cray after passing through the Thames Road Industrial Area to the south of the railway line. This potential flow route should be considered as part of any future development of this area.

Within Crayford town centre, around the junctions of London Road, Waterside Road and Crayford High Street, there are a significant number of reported surface water flooding incidents. These reported incidents do not however appear to be within identified areas potentially susceptible to surface water flooding. This is because the surface water flow route mapping involves the simulation of rainfall over the topography rather than the simulation of drainage networks. It is therefore likely that the reported incidents in the town centre are related to local capacity issues within the drainage network and/or because of drainage outlets into the River Cray are submerged by high water levels, thus restricting discharge from the drains.

5.2.4 Groundwater flood risk

The potential for groundwater emerging at the surface and causing localised flooding issues is highlighted in Figure D11 in Appendix D and described in Section 3.2.3 of the Level 1 SFRA. Within the Crayford sustainable growth area the base geology is chalk, which is known to be a major aquifer, and the geology mapping does not indicate the presence of a capping layer of impermeable London Clay. As such there is the potential for groundwater levels to rise to near the surface and in the lowest areas (e.g. the Crayford Marsh, outside of the growth area) emerge at the surface. The mapping presented in Figure D11 presents a representation of groundwater levels for the winter of 2001, based upon 10m groundwater levels issued by the Environment Agency. This mapping indicates that risk of groundwater levels being near or at the surface during prolonged wet periods is potentially high in the topographically low areas. The results presented in Figure D11 are indicative as they do not account for the role of the rivers Cray(located to the east), Shuttle (located to the south) and Thames (located to the north), which receive discharge from the groundwater.

The risk of groundwater flooding is however considered to be locally variable as the composition and stratigraphy of the overlying superficial deposits will influence how groundwater levels in the chalk aquifer will translated into groundwater levels within the superficial deposits.

5.3 Management of flood risk – through avoidance

Please read section 2.2.4 which describes the delineation of Functional Floodplain.

Options to reduce flood risk in Crayford are reported in the Crayford Flood Mitigation Study[22], which concludes that the most sustainable method of flood risk management is through the land use planning process with targeted

[22] London Borough of Bexley, Crayford Flood Mitigation Study, (2007), Entec.

redevelopment/regeneration of areas within the floodplain. Redevelopment of areas at risk of flooding has both the potential to reduce flood risks in the wider area, and onsite through improved building alignment, reduced building footprints, provision of safe escape routes and flood resilient building design.

5.3.1 Site allocations

Within the Crayford sustainable growth area the majority of the SHLAA sites are identified as being at some degree of fluvial flood risk. Both fluvial and tidal flood risks are predicted to impact some of the employment sites, but for the most part (i.e. with the exception of the Tower Retail Park and the Crayford Industrial Area) the employment sites are at a lower risk of flooding. Where possible, is it is recommended that all options to designate residential uses in the areas of least risk should be explored as part of the site allocation process.

In line with the Functional Floodplain guidance presented in section 2.2.4, the areas of fluvial Flood Zone 3 should be avoided where possible and currently undeveloped sites within the 1 in 20 year flood extent should be avoided. However, as stated above in section 5.2, the most sustainable method of flood risk management is through the land use planning process with targeted redevelopment/regeneration of areas within the floodplain. Moreover the requirement which states that development should not to increase the risk of flooding elsewhere means that one design solution would be that current building footprints within the floodplain should not be increased. Thus sites in Flood Zone 1 will offer potentially greater development flexibility.

5.3.2 Onsite land use planning

This process should be informed by the latest flood risk predictions, which can be requested from the Environment Agency. It is important that the recently updated 1 in 20 year flood extent is reviewed as part of this process. Even if an area of the 1 in 20 year floodplain is currently developed, redevelopment of a site within this area should seek to make space for water.

If the application of the Sequential Test confirms that there are no alternative sites available within Flood Zone 1, then it is important that onsite land use planning, which reflects the sequential risk based approach to avoiding flood risk, is applied. As part of the site planning of any redevelopment of brownfield sites, there are opportunities to reduce flood risks, by:

- Reducing the footprint of buildings on sites that are within the 1 in 20 year flood extent;
- Better aligning buildings to the direction of flood flow;
- Increasing the hydraulic efficiency of developments under flood conditions, by providing designated flood flow routes;
- On a case by case basis the possibility of allowing water to flow under a building should be discussed with the Environment Agency. The placement of buildings on ‘stilts’ is not considered a preferred option and is not one which would facilitate development on currently undeveloped sites. However,

the use of ‘slits’ may be considered to provide a local flood risk reduction benefit, if it can be demonstrated that this provides a betterment of the existing condition.

5.4 Management of flood risk – through design

5.4.1 Building design

The following are development design measures which could facilitate safe development, from a flood risk perspective, within the fluvial flood risk areas of the Crayford sustainable growth area. Management of flood risk through design should only be considered once the Sequential Test has been applied and it has been demonstrated that there are no other alternative sites available. Measures include:

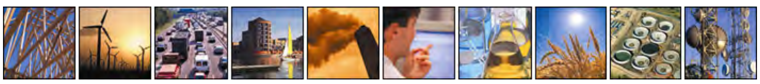
- Using ‘less vulnerable’ land use types, and residential uses that are **not** bedrooms, or living spaces that can become bedrooms, or bedrooms partitioned from communal living spaces, such as open plan living/kitchen/dining spaces, below the predicted peak flood water level;
- Providing safe escape from all units in the event of a flood. Where possible safe escape should be achieved, alternatively, it might be considered acceptable for escape routes to be exposed to a ‘caution’ flood hazard rating (less than 0.75 during the 1 in 100 year plus climate change event).
- Applying flood resilient and resistant design (see Section 6 of the Level 1 SFRA);
- Basements are not considered appropriate within the tidal or fluvial flood risk areas of the Crayford sustainable growth area.

5.4.2 Basements

It is recommended that habitable rooms in basements should not be permitted in Flood Zones 2 or 3. Adaptation of existing properties to include a basement for habitable rooms, or to create a habitable space from an existing non-habitable basement, should be discouraged in Flood Zones 2 and 3. It is however recognised that the implementation of this may be challenging, as basement development is sometimes classified as Permitted Development when within the bounds of the existing building. In this case, educating the public as to the dangers of adding or adapting basement space would be a possible approach.

Basements for less vulnerable uses or non habitable rooms must be designed with safe internal escape. Site specific analysis should accompany any proposal, to demonstrate that a proposed basement would not impact the flow of groundwater in such a way that the risk of groundwater flooding elsewhere is increased and to demonstrate that the basement will not be flooded by locally high groundwater levels.

Basements within flood zones 2 and 3 in the Crayford sustainable growth area should be avoided.



5.5 Management of flood risk – through emergency response

Unlike the Thamesmead and Abbey Wood and Belvedere sustainable growth areas, facilitating safe development through the provision of internal refuge should not be the preferred option, as all potential development sites are only partially located within the areas of predicted tidal or fluvial flood risk. Therefore, new development should allow for the safe evacuation of all units during the 1 in 100 year plus climate change fluvial event, and the 1 in 200 year plus climate change tidal event. Safe escape routes should not impede flood flows or increase the risk of flooding elsewhere by reducing floodplain storage. On a case by case basis and following detailed consultation with the Council (including the Council Emergency Planner) it might be considered acceptable to allow less vulnerable land uses to be developed, without safe escape, on the basis of there being a Flood Evacuation and Closure Plan being prepared and approved.

A Flood Evacuation and Closure Plan would be triggered on receipt of an Environment Agency flood warning (the level of warning, i.e. Warning or Severe Warning should be agreed on a site by site basis). This would then result in premises, such as a school or other community facility, or offices/commercial units, being closed and evacuated immediately. These premises would then need to remain closed until the flood warning was lifted. The approval of such a plan rests with the Council. The use of emergency plans to facilitate development should only be considered once all other options have been explored and exhausted.

5.6 Surface water management

The Crayford sustainable growth area is situated over Groundwater Source Protection Zones 1 (Inner protection zone), and 2 (Outer protection zone), and as such infiltration options are considered inappropriate due to the potential for groundwater contamination.

The piped drainage network has a finite capacity (not assumed to be more than the 1 in 30 year storm). As such it is important that any new development provides sufficient on site storage to attenuate surface water run-off from each site for events up to and including the 1 in 100 year plus climate change event. This is to ensure that any new development does not increase the risk of flooding elsewhere. Furthermore, it is highly likely that Thames Water will insist upon discharge rates not increasing above the current discharge rate.

In all cases drainage schemes prepared to support development proposals should provide storage for the 1 in 100 plus climate change critical storm.

The discharge rates from all sites should not allow unrestricted discharge rates for all storm events up to the 1 in 100 year +CC rate of discharge. It is recommended that the drainage strategy prepared for proposed development sites includes a review of greenfield and current discharge rates for storm events ranging from the 1 in 2 year to the 1 in 100 year storm including an allowance for climate change.

In order that flood risks are not increased, run-off rates for development should be managed to greenfield rates, which are defined as the runoff rates from a site, in its natural state, prior to any development. The only exceptions to this, where greater discharge rates may be acceptable, are where a pumped discharge would be required to meet the standards or where surface water drainage is to tidal waters and therefore would be able to discharge at unrestricted rates.

The drainage scheme proposed for the development should then either be to set the allowable discharge rate to the mean annual flood for all storms up to the 1 in 100-year+CC critical duration event, or have a variable discharge rate designed to mimic the relative increases in discharge that occur from an undeveloped site, in response to different storm probabilities. This can be achieved through the installation of hydro-brakes. The rationale for this is so that discharge from the site, post development, closely matches the current pattern of discharge.

The range of storms should be agreed with the Environment Agency, and both the Environment Agency and Thames Water should be consulted if the discharge is to the piped network, rather than directly to the ditches, dykes or canals. Direct discharge should be agreed with the Environment Agency and Bexley's Drainage Team in advance, and the proposed drainage scheme should include measures to ensure that contaminants from the site are not discharged into the river system.

Measures to provide attenuation in the Crayford sustainable growth area include:

- Where possible the use of green roofs, rainwater harvesting and other source control measures should be utilised;
- Swales and attenuation basins If these features are not lined, a site specific infiltration test will be required to demonstrate the effectiveness of infiltration and an assessment of groundwater conditions and land contamination issues;
- Creation of attenuation ponds and/or wetland areas;
- Using the topography to create linked SuDS features and thus increase the opportunity for ecological and public realm enhancements;
- Underground storm cells or oversized pipes. These measures should be viewed as the least preferred option as they offer no wider (ecological, water quality or amenity) values. Their use should be supported by a demonstration that other more sustainable options are not technically feasible.

Further guidance on the selection of SuDS techniques is provided in the Level 1 SFRA (2010).

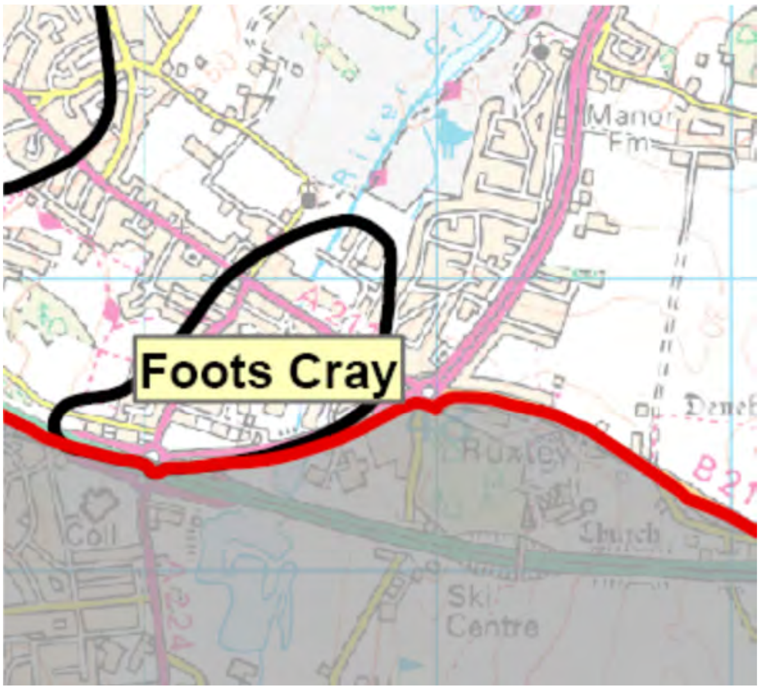
6. Foots Cray sustainable growth area

This section is supported by the mapping provided in Appendix E.

6.1 Introduction

The Foots Cray sustainable growth area, focused on the Foots Cray Business Area (a preferred office location), is located in the very south of the Borough adjacent to the borough boundary with Bromley. Figure 6.1 illustrates the location of this area. The flood risks and flood risk management guidance in the Foots Cray sustainable growth area is very similar to those in both the Old Bexley and Crayford sustainable growth areas, and should be considered together, thus allowing for the development of a consistent 'River Cray Corridor' approach to be adopted for land use planning and development control.

Figure 6.1 Foots Cray sustainable growth area



Extract from Figure A1 in Appendix A

6.2 Assessment of flood risk

The three sources of flood risk in this area that the Level 2 SFRA will focus on are: fluvial flood risk, surface water flood risk and groundwater flood risk. Please consult Section 2 of this report for details of the assessment methodology applied.

6.2.1 Fluvial flood risk

The Level 1 SFRA identified that the predominant flood risk in the Foots Cray sustainable growth area is from the River Cray, which flows from south to north through this area. The SFRA flood zones include zones 2 and 3 and these have been used to form the assessment of flood risk to each site, as presented in Figures E1 and E2 in Appendix E. As detailed in Section 2.2.4, the new Environment Agency flood mapping for the River Cray supersedes the SFRA Flood Zones and includes the prediction of the 1 in 20 year flood envelope. **The reader is advised to consult section 2.2.4 of this report for details on the Functional Floodplain delineation in Bexley.**

All the potential Employment and SHLAA sites in the Foots Cray sustainable growth area, which are in zones of flood risk, are located on currently developed sites. As such, the areas of the 1 in 20 year floodplain which these sites occupy is classified as Flood Zone 3a and not 3b.

For the purposes of informing the spatial planning and site allocation process this approach is appropriate, but is essential that the new flood zone and modelled flood level information is obtained from the Environment Agency as part of any site specific investigation and Flood Risk Assessment.

6.2.2 Surface water flood risk

Figure E3 illustrates the results of the surface water modelling undertaken as part of the Level 1 SFRA, included on this mapping are a series of reported flooding incidents which were collated by the Council and issued to Entec in August 2010.

A significant potential surface water flow route is predicted to be present across the west of the sustainable growth area. This route is predicted to originate from the A20, before crossing Watery Lane and Cray Road before flowing through the large industrial site off Powerscroft Road. The surface water modelling predicts that this flow route then flows into the River Cray. It is therefore important that this potential flow route is considered as part of any future development of this site.

There are no reported incidents of surface water flooding within the Foots Cray sustainable growth area.

6.2.3 Groundwater flood risk

The potential for groundwater emerging at the surface and causing localised flooding issues is highlighted in Figure E4 in Appendix E and described in Section 3.2.3 of the Level 1 SFRA. Within the Foots Cray sustainable growth area the base geology is chalk, which is known to be a major aquifer and the geology mapping does not indicate the presence of a capping layer of impermeable London Clay. As such there is the potential for groundwater levels to be near the surface in the lowest parts of this sustainable growth area. The mapping presented in Figure E4 presents a representation of groundwater levels for the winter of 2001, based upon 10m groundwater levels issued by the Environment Agency. This mapping indicates that risk of groundwater levels being near or at the surface during prolonged wet periods. The results presented in Figure E4 are indicative as they do not account for the role of the

River Cray which flows through the centre of the Foots Cray sustainable growth area and which will receive discharge from the groundwater.

The risk of groundwater flooding is however considered to be locally variable as the composition and stratigraphy of the overlying superficial deposits will influence how groundwater levels in the chalk aquifer will translated into groundwater levels within the superficial deposits.

6.3 Management of flood risk – through avoidance

Please read section 2.2.4 which describes the delineation of Functional Floodplain.

6.3.1 Site allocations

The identified SHLAA sites, adjacent to the A20 are assessed as being in Flood Zone 1 and the Foots Cray Business Area sites include areas of Flood Zones 1, 2 and 3. The two large sites to the south of Foots Cray High Street only include small areas of Flood Zone 2 and 3, with the majority of each site being assessed as Flood Zone 1. The relative coverage of the higher risk flood zones increases on the sites to the north of Foots Cray High Street.

Within the boundary of this sustainable growth area, the sequential risk based approach to land use planning has been followed, as the more vulnerable land use types (e.g. residential) are identified in the areas of least flood risk and less vulnerable land use types have been potentially identified for areas of higher flood risk.

6.3.2 Onsite land use planning

This process should be informed by the latest flood risk predictions which can be requested from the Environment Agency. It is important that the recently updated 1 in 20 year flood extent is reviewed as part of this process. Even if an area of the 1 in 20 year floodplain is currently developed, redevelopment of a site within this area should seek to make space for water.

If the application of the Sequential Test confirms that there are no alternative sites available within Flood Zone 1, then it is important that on site land use planning, which reflects the sequential risk based approach to avoiding flood risk, is applied. As part of the site planning of any redevelopment of brownfield sites, there are opportunities to reduce flood risks, by:

- Reducing the footprint of buildings on sites that are within the 1 in 20 year flood extent;
- Better aligning buildings to the direction of flood flow;
- Increasing the hydraulic efficiency of developments under flood conditions, by providing designated flood flow routes;
- On a case by case basis the possibility of allowing water to flow under a building should be discussed with the Environment Agency. The placement of buildings on ‘stilts’ is not considered a preferred

option and is not one that would facilitate development on currently undeveloped sites. However, the use of 'slits' may be considered to provide a local flood risk reduction benefit, if it can be demonstrated that this provides a betterment of the existing condition.

6.4 Management of flood risk – through design

6.4.1 Building design

The following are development design measures which could facilitate safe development, from a flood risk perspective, within the fluvial flood risk areas of the Foots Cray sustainable growth area. Management of flood risk through design should only be considered once the Sequential Test has been applied and it has been demonstrated that there are no other alternative sites available. Measures include:

- Using 'less vulnerable' land use types, and residential uses that are **not** bedrooms, or living spaces that can become bedrooms, or bedrooms partitioned from communal living spaces, such as open plan living/kitchen/dining spaces, below the predicted peak flood water level;
- Providing safe escape from all units in the event of a flood. Where possible safe escape should be achieved, alternatively, it might be considered acceptable for escape routes to be exposed to a 'caution' flood hazard rating (less than 0.75 during the 1 in 100 year plus climate change event).
- Applying flood resilient and resistant design (see Section 6 of the Level 1 SFRA);
- Basements are not considered appropriate within the fluvial flood risk areas of the Foots Cray sustainable growth area.

6.4.2 Basements

It is recommended that habitable rooms in basements should not be permitted in Flood Zones 2 or 3. Adaptation of existing properties, to include a basement for habitable rooms, or to create a habitable space from an existing non-habitable basement, should be discouraged in Flood Zones 2 and 3. It is however recognised that the implementation of this may be challenging, as basement development is sometimes classified as Permitted Development when within the bounds of the existing building. In this case, educating the public as to the dangers of adding or adapting basement space would be a possible approach.

Basements for less vulnerable uses or non habitable rooms must be designed with safe internal escape. Site specific analysis should accompany any proposal, to demonstrate that a proposed basement would not impact the flow of groundwater in such a way that the risk of groundwater flooding elsewhere is increased and to demonstrate that the basement will not be flooded by locally high groundwater levels.

Basements within the fluvial flood risks zones in the Foots Cray sustainable growth area should be avoided.

6.5 Management of flood risk – through emergency response

Unlike the Thamesmead & Abbey Wood and Belvedere sustainable growth areas, facilitating safe development through the provision of internal refuge, should not be the preferred option as all potential development sites are only partially located within the areas of predicted tidal or fluvial flood risk. Therefore, new development should allow for the safe evacuation of all units during the 1 in 100 year plus climate change fluvial event, and the 1 in 200 year plus climate change tidal event. Safe escape routes should not impede flood flows or increase the risk of flooding elsewhere by reducing floodplain storage. On a case by case basis and following detailed consultation with the Council (including the Council Emergency Planner) it might be considered acceptable to allow less vulnerable land uses to be developed, without safe escape, on the basis of there being a Flood Evacuation and Closure Plan being prepared and approved. This would not be appropriate, however, for residential development.

A Flood Evacuation and Closure Plan would be triggered on receipt of an Environment Agency flood warning (the level of warning, i.e. Warning or Severe Warning should be agreed on a site by site basis). This would then result in premises, such as a school or other community facility, or offices/commercial units, being closed and evacuated immediately. These premises would then need to remain closed until the flood warning was lifted. The approval of such a plan rests with the Council. The use of emergency plans to facilitate development should only be considered once all other options have been explored and exhausted.

6.6 Surface water management

Within the Foots Cray sustainable growth area the underlying geology suggests that infiltration techniques may be effective. The potential effectiveness for infiltration techniques is reduced by the presence of Ground Water Source Protection Zones and because of the potential for high groundwater levels. The suitability for infiltration techniques should be evaluated on a sit by site basis, which needs to be informed by infiltration testing and supported by consultation with the Environment Agency. Figure E5 in Appendix provides a high level assessment of infiltration potential.

The piped drainage network has a finite capacity (not assumed to be more than the 1 in 30 year storm). As such it is important that any new development provides sufficient on site storage to attenuate surface water run-off from each site for events up to and including the 1 in 100 year plus climate change event. This is to ensure that any new development does not increase the risk of flooding elsewhere. Furthermore, it is highly likely that Thames Water will insist upon discharge rates not increasing above the current discharge rate.

In all cases drainage schemes prepared to support development proposals should provide storage for the 1 in 100+CC (climate change) critical storm.

The discharge rates from all sites should not allow unrestricted discharge rates for all storm events up to the 1 in 100 year +CC rate of discharge. It is recommended that the drainage strategy prepared for proposed development sites includes a review of greenfield and current discharge rates for storm events ranging from the 1 in 2 year to the 1 in 100 year storm including an allowance for climate change.

In order that flood risks are not increased, run-off rates for development should be managed to greenfield rates, which are defined as the runoff rates from a site, in its natural state, prior to any development. The only exceptions to this, where greater discharge rates may be acceptable, are where a pumped discharge would be required to meet the standards or where surface water drainage is to tidal waters and therefore would be able to discharge at unrestricted rates.

The drainage scheme proposed for the development should then either be to set the allowable discharge rate to the mean annual flood for all storms up to the 1 in 100-year+CC critical duration event, or have a variable discharge rate designed to mimic the relative increases in discharge that occur from an undeveloped site, in response to different storm probabilities. This can be achieved through the installation of hydro-brakes. The rationale for this is so that discharge from the site, post development, closely matches the current pattern of discharge.

The range of storms should be agreed with the Environment Agency, and both the Environment Agency and Thames Water should be consulted if the discharge is to the piped network, rather than directly to the ditches, dykes or canals. Direct discharge should be agreed with the Environment Agency and Bexley's Drainage Team in advance, and the proposed drainage scheme should include measures to ensure that contaminants from the site are not discharged into the river system.

Measures to provide attenuation in the Foots Cray sustainable growth area include:

- Where possible the use of green roofs, rainwater harvesting and other source control measures should be utilised;
- Swales and attenuation basins If these features are not lined, a site specific infiltration test will be required to demonstrate the effectiveness of infiltration and an assessment of groundwater conditions and land contamination issues;
- Creation of attenuation ponds and/or wetland areas;
- Using the topography to create linked SuDS features and thus increase the opportunity for ecological and public realm enhancements;
- Underground storm cells or over sized pipes. These measures should be viewed as the least preferred option as they offer no wider (ecological, water quality or amenity) values. Their use should be supported by a demonstration that other more sustainable options are not technically feasible.

Further guidance on the selection of SuDS techniques is provided in the Level 1 SFRA (2010).

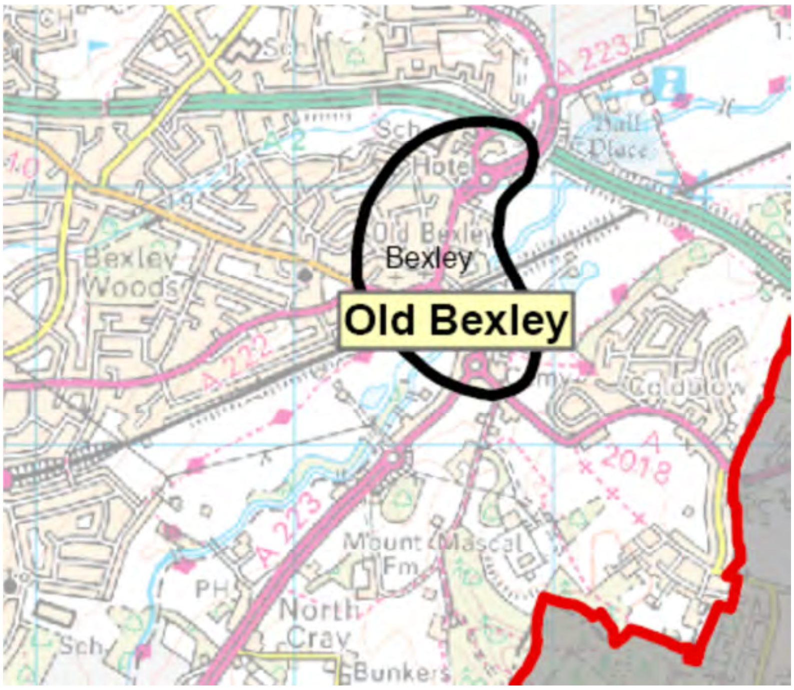
7. Old Bexley sustainable growth area

This section is supported by the mapping provided in Appendix F.

7.1 Introduction

The Old Bexley sustainable growth area, focused on Bexley town centre, is located in the southeast of the Borough. Figure 7.1 illustrates the location of this area. The flood risks and flood risk management guidance in Old Bexley is very similar to those in both the Crayford and Foots Cray sustainable growth areas, and should be considered together, thus allowing for the development of a consistent 'River Cray Corridor' approach to be adopted for land use planning and development control.

Figure 7.1 Old Bexley sustainable growth area



Extract from Figure A1 in Appendix A

7.2 Assessment of flood risk

The three sources of flood risk in this area that the Level 2 SFRA will focus on are: fluvial flood risk, surface water flood risk and groundwater flood risk. Please consult Section 2 of this report for details of the assessment methodology applied.

7.2.1 Fluvial flood risk

The Old Bexley sustainable growth area is situated on the banks of the River Cray, downstream of Foots Cray and immediately upstream of the confluence between the rivers Cray and Shuttle. Fluvial flood risk is a potentially significant flood risk in this growth area. The SFRA flood zones include zones 2 and 3 and these have been used to form the assessment of flood risk to each site, as presented in Figures F1 and F2 in Appendix F. As detailed in Section 2.2.4, the new Environment Agency flood mapping for the River Cray supersedes the SFRA Flood Zones and includes the prediction of the 1 in 20 year flood envelope. **The reader is advised to consult section 2.2.4 of this report for details on the Functional Floodplain delineation in Bexley.**

All the potential Employment and SHLAA sites in the Old Bexley sustainable growth area, which are in zones of flood risk, are located on currently developed sites. As such, the areas of the 1 in 20 year floodplain which these sites occupy are classified as Flood Zone 3a and not 3b.

For the purposes of informing the spatial planning and site allocation process this approach is appropriate, but is essential that the new flood zone and modelled flood level information is obtained from the Environment Agency as part of any site specific investigation and Flood Risk Assessment.

7.2.2 Surface water flood risk

Figure F3 illustrates the results of the surface water modelling undertaken as part of the Level 1 SFRA, included on this mapping are a series of reported flooding incidents which were collated by the Council and issued to Entec in August 2010.

A significant potential surface water flow route is predicted to be present in the south of the growth area. There are a couple of reported incidents of surface water flooding, along North Cray Road, which correlate with this predicted flow route. This potential flow route impacts the SHLAA site that is located adjacent to Vicarage Road and should be considered as part of any future development of this site.

7.2.3 Groundwater flood risk

The potential for groundwater emerging at the surface and causing localised flooding issues is highlighted in Figure F4 in Appendix F and described in Section 3.2.3 of the Level 1 SFRA. Within the Old Bexley sustainable growth area the base geology is chalk, which is known to be a major aquifer and the geology mapping does not indicate the presence of a capping layer of impermeable London Clay. A such there is the potential for groundwater levels to present a risk in the lowest parts of this sustainable growth area. The mapping presented in Figure F4 presents a representation of groundwater levels for the winter of 2001, based upon 10m groundwater levels issued by the Environment Agency. This mapping indicates that risk of groundwater levels being near or at the surface during prolonged wet periods is potentially high in the topographically low areas. The results presented in Figure F4 are indicative as they do not account for the role of the rivers Cray and Shuttle which receive discharge from groundwater. The risk of groundwater flooding is however considered to be locally variable as the composition and stratigraphy of the overlying superficial deposits will influence how groundwater levels in the chalk aquifer will translated into groundwater levels within the superficial deposits.

7.3 Management of flood risk – through avoidance

Please read section 2.2.4 which describes the delineation of Functional Floodplain.

7.3.1 Site allocations

There are five potential SHLAA sites identified within the Old Bexley sustainable growth area, three of which are assessed as being at significant risk of fluvial flooding. The fourth and fifth sites are located adjacent to Vicarage Road in the south and Southwold Road in the north and are currently assessed as being in Flood Zone 1.

The SHLAA site located to the north of the railway line is in Flood Zones 1, 2 and 3 and therefore should be suitable for mixed use development with the sequential approach applied on site The SHLAA site in the north, adjacent to Bourne Road is also predicted to be exposed to a range of flood risks, including zones 1, 2 and 3. Using the current flood risk predictions, about half the site is located within Flood Zone 1. The range of potential fluvial flood risks indicate that this site would potentially be suitable for a mixed us development, in which the sequential approach to land use planning could be applied (see Section 7.3.2).

The site immediately to the south of the railway is almost entirely within Flood Zone 2 and is therefore only suitable for residential land uses on passing both the Sequential Test and Exception Test.

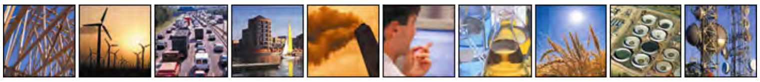
The delineation of flood risks to each site should be confirmed with the Environment Agency when the latest flood modelling extents are publicly available.

7.3.2 Onsite land use planning

This process should be informed by the latest flood risk predictions which can be requested from the Environment Agency. It is important that the recently updated 1 in 20 year flood extent is reviewed as part of this process. Even if an area of the 1 in 20 year floodplain is currently developed, redevelopment of a site within this area should seek to make space for water.

If the application of the Sequential Test confirms that there are no alternative sites available within Flood Zone 1, then it is important that on site land use planning, which reflects the sequential risk based approach to avoiding flood risk, is applied. As part of the site planning of any redevelopment of brownfield sites, there are opportunities to reduce flood risks, by:

- Reducing the footprint of buildings on sites that are within the 1 in 20 year flood extent;
- Better aligning buildings to the direction of flood flow;



- Increasing the hydraulic efficiency of developments under flood conditions, by providing designated flood flow routes;
- On a case by case basis, considering the possibility of allowing water to flow under a building should be discussed with the Environment Agency. The placement of buildings on 'stilts' is not considered a preferred option and is not one that would facilitate development on currently undeveloped sites. However, the use of 'slits' may be considered to provide a local flood risk reduction benefit, if it can be demonstrated that this provides a betterment of the existing condition.

7.4 Management of flood risk – through design

7.4.1 Building design

The following are development design measures which could facilitate safe development, from a flood risk perspective, within the fluvial flood risk areas of the Old Bexley sustainable growth area. Management of flood risk through design should only be considered once the Sequential Test has been applied and it has been demonstrated that there are no other alternative sites available. Measures include:

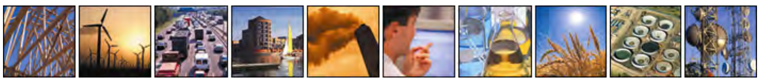
- Using 'less vulnerable' land use types, and residential uses that are **not** bedrooms, or living spaces that can become bedrooms, or bedrooms partitioned from communal living spaces, such as open plan living/kitchen/dining spaces, below the predicted peak flood water level;
- Providing safe escape from all units in the event of a flood. Where possible safe escape should be achieved, alternatively, it might be considered acceptable for escape routes to be exposed to a 'caution' flood hazard rating (less than 0.75 during the 1 in 100 year plus climate change event).
- Applying flood resilient and resistant design (see Section 6 of the Level 1 SFRA);
- Basements are not considered appropriate within the fluvial flood risk areas of the Old Bexley sustainable growth area.

7.4.2 Basements

It is recommended that habitable rooms in basements should not be permitted in Flood Zones 2 or 3. Adaptation of existing properties, to include a basement for habitable rooms, or to create a habitable space from an existing non-habitable basement, should be discouraged in Flood Zones 2 and 3. It is however recognised that the implementation of this may be challenging, as basement development is sometimes classified as Permitted Development when within the bounds of the existing building. In this case, educating the public as to the dangers of adding or adapting basement space would be a possible approach.

Basements for less vulnerable uses or non habitable rooms must be designed with safe internal escape. Site specific analysis should accompany any proposal, to demonstrate that a proposed basement would not impact the flow of groundwater in such a way that the risk of groundwater flooding elsewhere is increased and to demonstrate that the basement will not be flooded by locally high groundwater levels.

Basements within the fluvial flood risk zones in the Old Bexley sustainable growth area should be avoided.



7.5 Management of flood risk – through emergency response

Unlike the Thamesmead and Abbey Wood and Belvedere sustainable growth areas, facilitating safe development through the provision of internal refuge, should not be the preferred option as all potential development sites are only partially located within the areas of predicted tidal or fluvial flood risk. Therefore, new development should allow for the safe evacuation of all units during the 1 in 100 year plus climate change fluvial event, and the 1 in 200 year plus climate change tidal event. Safe escape routes should not impede flood flows or increase the risk of flooding elsewhere by reducing floodplain storage. On a case by case basis and following detailed consultation with the Council (including the Council Emergency Planner) it might be considered acceptable to allow less vulnerable land uses to be developed, without safe escape, on the basis of there being a Flood Evacuation and Closure Plan being prepared and approved. This would not be appropriate, however, for residential development.

A Flood Evacuation and Closure Plan would be triggered on receipt of an Environment Agency flood warning (the level of warning, i.e. Warning or Severe Warning should be agreed on a site by site basis). This would then result in premises, such as a school or other community facility, or offices/commercial units, being closed and evacuated immediately. These premises would then need to remain closed until the flood warning was lifted. The approval of such a plan rests with the Council. The use of emergency plans to facilitate development should only be considered once all other options have been explored and exhausted.

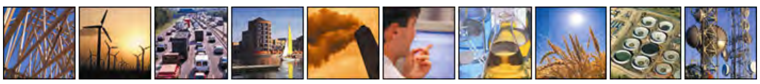
7.6 Surface water management

Within the Old Bexley sustainable growth area the underlying geology suggests that infiltration techniques may be effective. The potential effectiveness for infiltration techniques is reduced by the presence of Ground Water Source Protection Zones (see Figure F5 in Appendix F) and because of the potential for high groundwater levels (in the topographically lower areas). The suitability for infiltration techniques should be evaluated on a site by site basis, which needs to be informed by infiltration testing and supported by consultation with the Environment Agency.

The piped drainage network has a finite capacity (not assumed to be more than the 1 in 30 year storm). As such it is important that any new development provides sufficient on site storage to attenuate surface water run-off from each site for events up to and including the 1 in 100 year plus climate change event. This is to ensure that any new development does not increase the risk of flooding elsewhere. Furthermore, it is highly likely that Thames Water will insist upon discharge rates not increasing above the current discharge rate.

In all cases drainage schemes prepared to support development proposals should provide storage for the 1 in 100+CC (climate change) critical storm.

The discharge rates from all sites should not allow unrestricted discharge rates for all storm events up to the 1 in 100 year +CC rate of discharge. It is recommended that the drainage strategy prepared for proposed development sites includes a review of greenfield and current discharge rates for storm events ranging from the 1 in 2 year to the 1 in 100 year storm including an allowance for climate change.



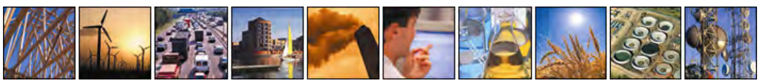
In order that flood risks are not increased, run-off rates for development should be managed to greenfield rates, which are defined as the runoff rates from a site, in its natural state, prior to any development. The only exceptions to this, where greater discharge rates may be acceptable, are where a pumped discharge would be required to meet the standards or where surface water drainage is to tidal waters and therefore would be able to discharge at unrestricted rates.

The drainage scheme proposed for the development should then either be to set the allowable discharge rate to the mean annual flood for all storms up to the 1 in 100-year+CC critical duration event, or have a variable discharge rate designed to mimic the relative increases in discharge that occur from an undeveloped site, in response to different storm probabilities. This can be achieved through the installation of hydro-brakes. The rationale for this is so that discharge from the site, post development, closely matches the current pattern of discharge.

The range of storms should be agreed with the Environment Agency, and both the Environment Agency and Thames Water should be consulted if the discharge is to the piped network, rather than directly to the ditches, dykes or canals. Direct discharge should be agreed with the Environment Agency and Bexley's Drainage Team in advance, and the proposed drainage scheme should include measures to ensure that contaminants from the site are not discharged into the river system.

Measures to provide attenuation in the Old Bexley sustainable growth area include:

- Where possible the use of green roofs, rainwater harvesting and other source control measures should be utilised;
- Swales and attenuation basins If these features are not lined, site specific infiltration test would be required to demonstrate the effectiveness of infiltration and an assessment of groundwater conditions and land contamination issues;
- Creation of attenuation ponds and/or wetland areas;
- Using the topography to create linked SuDS features and thus increase the opportunity for ecological and public realm enhancements;
- Under ground storm cells or over sized pipes. These measures should be viewed as the least preferred option as they offer no wider (ecological, water quality or amenity) values. There use should be supported by a demonstration that other more sustainable options are not technically feasible.



8. Further guidance on the selection of SuDS techniques is provided in the Level 1 SFRA (2010).Summary of recommendations

Recommendations and guidance are presented throughout the Level 2 SFRA; the specifics vary depending upon the location and flood risk. For example the flood risk management through design and through emergency response are different for the residual tidal risk zones and the fluvial risk zones. The guidance within each of these distinctly different flood risk areas has been made consistent between each of the sustainable growth areas.

The points below summaries the recommendations made in this Level 2 SFRA:

- This Level 2 SFRA includes a prediction of the 1 in 20 year flood event associated with the River Cray in the Crayford sustainable growth area. These outputs were generated as part of the modelling work undertaken as part of the Crayford Town Centre SFRA in 2007. The Environment Agency has recently completed a re-mapping exercise along the rivers Cray and Shuttle. This includes flood extents and flood water levels associated with the 1 in 20, 1 in 100, 1 in 100 plus climate change and the 1 in 1000 year events. The existing flood event outlines are sufficient to inform the spatial planning process, but the new data should be obtained as part of any site specific work;

- Currently developed areas of the 1 in 20 year flood extent should be classified as areas of Flood Zone 3a, as they are not considered functional parts of the floodplain, whereas all areas of undeveloped land within the 1 in 20 year flood extent should be classified as Flood Zone 3b. Redevelopment/renewal/intensification opportunities should only be taken on brownfield sites in the 1 in 20 year flood extent in the Bexley Core Strategy sustainable growth areas. See Section 2.2.4 for full details. Revised Environment Agency floodplain mapping should be consulted to define the extent of the 1 in 20 year flood risk zone;

- In line with the second point, only brownfield sites within the Bexley Core Strategy sustainable growth areas should be considered for redevelopment within fluvial Flood Zone 3, as the remainder of fluvial Flood Zone 3 (i.e. that which is within the 1 in 20 year flood extent) is designated as Functional Floodplain. The site layout and building design when sites are proposed for redevelopment should result in a reduction in local flood risk, through the incorporation of designated flood flow routes and by improving the hydraulic efficiency of buildings (i.e. reduce the resistance of the building to flood flows by aligning buildings to the direction of flow);

- It is recommended that SHLAA sites located within Flood Zone 3a are avoided if possible. It is however recognised that in locations such as the London Plan Opportunity Areas in the borough that are in need of regeneration it is likely that residential sites will be allocated within Flood Zone 3a so as to meet the London Plan housing requirements. In any event, areas within Flood Zone 3a proposed as sustainable growth locations that have passed the Sequential Test will need to pass the Exception Test;

- In the residual tidal flood risk zones which are present in the Thamesmead and Erith Marshes embayment, and include the sustainable growth areas of Belvedere and Thamesmead and Abbey

Wood, less vulnerable land use types should be used below the predicted peak flood level (1 in 200 year plus climate change) wherever possible.

- However, relaxations to the 1 in 200 year plus climate change requirement may apply. An example of such a relaxation would be allowing residential uses (which fall into the 'more vulnerable' classification) below flood levels, **provided that they are not bedrooms, or any other living spaces that could be converted into bedrooms**. Providing that room use with a low consequence from flooding can be reasonably assured in perpetuity, assurance that could be achieved through a planning condition and a restriction on permitted development within a building footprint, then it may be considered below the predicted peak flood water level. Such a design would require the floor levels for bedrooms to be set above the predicted peak 1 in 200 year level plus climate change allowance;

- All occupied development (including community facilities, and commercial or industrial units) within the tidal residual flood risk zone must include an internal safe refuge with a floor level set above the 1 in 200 year plus climate change maximum predicted flood level;

- Ground floor levels for all occupied development types (including commercial and industrial) within the fluvial flood zones should be set above the predicted 1 in 100 year plus climate change peak flood water level. This level should be requested from the Environment Agency;

- Within the residual tidal risk areas where safe escape cannot be facilitated, safe development can be achieved through provision of dry refuge within each building, the details of which need to be reviewed on case by case basis with the Council. Sites at the margin of the residual risk zone should seek to achieve safe escape through the site layout and design;

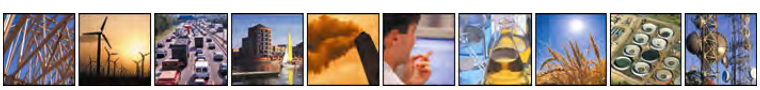
- Within the fluvial flood risk zones safe development must include the provision of safe access and egress throughout a flood event. For sites where this is not possible, safe development could be achieved through the preparation and approval of an Emergency Plan (this would not be appropriate, however, for residential development). The details of which should be considered on a case by case basis with the Environment Agency and the Councils Emergency Planning Officer;

- Basements are not considered appropriate in Flood Zones 2 or 3 (either fluvial or tidal);

- In order that flood risks are not increased, run-off rates for development should be managed to greenfield rates, which are defined as the runoff rates from a site, in its natural state, prior to any development. The only exceptions to this, where greater discharge rates may be acceptable, are where a pumped discharge would be required to meet the standards or where surface water drainage is to tidal waters and therefore would be able to discharge at unrestricted rates.

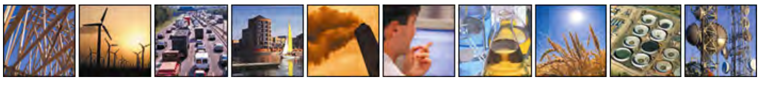
- All new development should provide attenuation for the 1 in 100 year plus climate change storm. For development proposals on sites of 0.25 hectares or larger in size, this needs to be identified in a drainage strategy that is submitted alongside a planning application. The rate of discharge should not increase post development. The allowable discharge rate (i.e. the current rate) is an important factor in determining the required attenuation volume, as such the allowable discharge rate should be calculated and agreed with Thames Water (if discharging to the public sewers) or the Environment Agency (if discharging directly to water bodies). The drainage schemes should control discharges for events up to the 1 in 100 year plus climate change as it is not considered acceptable to allow discharge at a 1 in

100 year plus climate change rate, during a 1 in 10 year storm. This situation can be managed through the use of hydro-brakes.



Appendix A
Level 2 mapping – borough wide

Please see appendices document (Appendix A)



Appendix B Level 2 mapping – Thamesmead and Abbey Wood and Belvedere sustainable growth areas

Please see appendices document (Appendix B)

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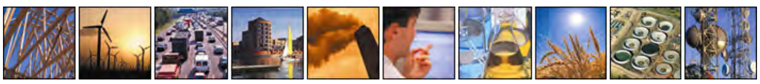
Appendix C
Level 2 mapping – Erith and Slade Green sustainable growth area

Please see appendices document (Appendix C)



Appendix D
Level 2 mapping – Crayford sustainable growth area

Please see appendices document (Appendix D)

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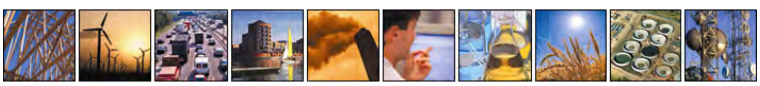
Appendix E
Level 2 mapping – Foots Cray sustainable growth area

Please see appendices document (Appendix E)



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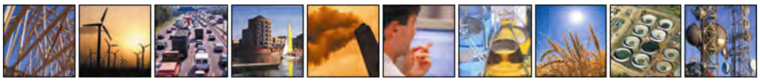
Appendix F
Level 2 mapping – Old Bexley sustainable growth area

Please see appendices document (Appendix F)



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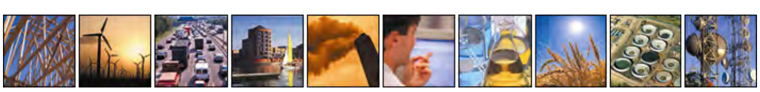
Appendix G
TuFLOW Modelling Report

Please see appendices document (Appendix G)



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TuFLOW Breach Modelling Report

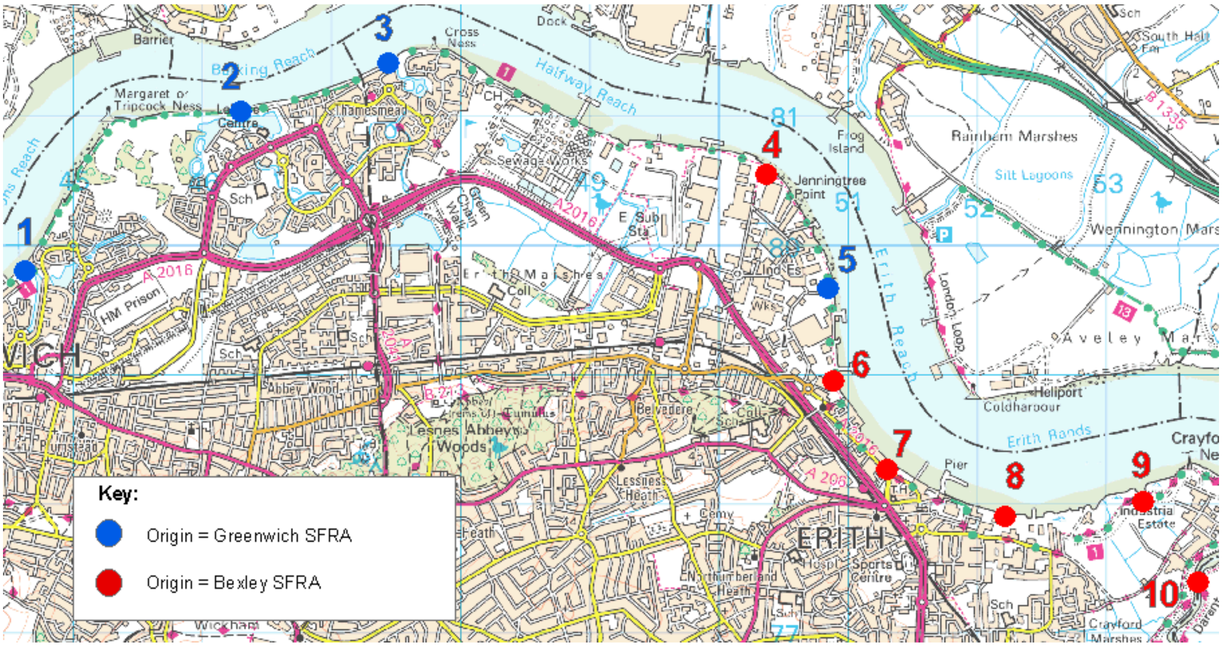
Introduction

Breach simulations were modelled at strategic points along the Thames defences, the locations of which were identified through consultation with the Environment Agency. Tidal hydrographs for the Thames and the topographic data (LiDAR) was issued by the Environment Agency.

TuFLOW is a computational engine that provides two-dimensional (2D) and one- dimensional (1D) solutions of free-surface flow to simulate flood propagation. It is recognised by the Environment Agency and Defra as being a preferred approach[23] and is commonly used for modelling the tidal Thames floodplain. TuFLOW was also used for the purposes of consistency as the recently completed Greenwich SFRA used TuFLOW to evaluate the level of residual risk in the part of the Thamesmead embayment which falls within the Borough of Greenwich. The Greenwich SFRA modelling, which was undertaken by Entec and JBA Consulting, has been incorporated into the Bexley SFRA. The Bexley SFRA includes the output of 10 individual breach models, four of which were taken from the Greenwich SFRA and the remaining six were built for the Bexley SFRA. Figure G1 illustrates the origin of 10 breaches. For completeness, the Bexley SFRA Modelling Appendix Report contains information relating to the four Greenwich SFRA models. The breach locations are numbered from west to east.

[23] Defra/Environment Agency (2006). ***R&D \Output: Flood Risk to People – Phase 2.*** FD231/TR2 Guidance Document.

Figure G.1 The Breach Locations Modelled in the Bexley and Greenwich SFRAs



The Greenwich SFRA breaches were numbered west to east. However locations 1, 2, 3 and 5 in this Figure were numbered 7, 8 ,9 and 10 in the Greenwich SFRA.

Model Specifics

TUFLOW was used for the breach and overtop simulations undertaken as part of this SFRA. Version TUFLOW.2008-08-AA-iSP was used and was the most recent version available at the time of modelling. The modelling of the embayment was largely two-dimensional. For breach locations 1 to 7, the model setup included 3 one-dimensional elements to represent culverts. Two of these related to the culvert passing beneath the Southern Outfall Sewer. In representing the one-dimensional elements, TUFLOW's 1-D solution scheme; ESTRY was implemented. The use of the 1-D solution of TUFLOW, enables the precise modelling of hydraulic features which are too small to accurately be captured within the model grid (which is 10m in size).

The British National Grid was the projection used for all the modelling.

Breach Configuration

Figure B.1 illustrates the location of the 10 models that were used to define the level of residual risk in Bexley. Locations 1 to 9 were breach models, breach 10 on the other hand is an overtopping model. Location 10 involved the over topping of the River Darent flood defences, under the assumption that the Darent flood barrier was not closed during the simulated 1 in 200 year tidal event.

When modelling a breach simulation, it is the Environment Agency's advice to differentiate between hard and soft defences. The reason for this is due to the impact the defence type can have on likely breach width and possible time to repair the defence. The Environment Agency's advice on modelling the two types of defence is presented below:

- ***Hard defences***, examples of these defences include concrete wall or sheet metal pilings. The modelled breach width for a hard defence is 20m. Two tidal cycles are used when simulating a breach of a hard defence (approximating 23 hrs to get the full rise and fall of two tidal cycles); and
- ***Soft defences*** are associated with earth embankments. Some soft defences may have a hard-capping; however, if the core of the structure is not strengthened, then the structure is said to be a soft defence. The breach width for a soft defence is 50m and three tidal cycles (approximately 33hrs to get the full rise and fall of all three tidal cycles).

Invert Levels

Table G.1 presents the modelled invert levels of the nine breach models and the modelled defence crest height of the River Darent defences in model 10.

Table G.1 Breach Locations and Characteristics

Breach Location	Type of Defence	Breach Width (m)	Duration of Simulation (hrs)	Invert Level (m AOD)
1	Hard	20	23	0
2	Hard	20	23	-0.3
3	Hard	20	23	-0.5
4	Hard	20	23	1.1
5	Soft	50	33	0.8
6	Hard	20	23	2.2
7	Hard	20	23	4.7
8	Hard	20	23	5.05
9	Soft	50	33	1.12
10	Overtop	Overtop (1100m)	33	5.5 (defence crest)

Model Assumptions

A number of assumptions and approximations had to be made in the modelling process, these are outlined below.

Simulating Defence Breaches in TuFLOW

A '***dam failure***' scenario, i.e. the situation where a failure in the defences occurs whilst the tide level in the Thames is at its peak, cannot accurately be modelled in TuFLOW. As such, the modelling in this SFRA simulates the ***breach*** to exist at the start of the simulation. In this way, flooding occurs in the embayment once the tide levels reaches and exceeds the invert level of the breach. This approach does not therefore simulate the shock wave that might be associated with a ***'dam failure***' and as such there is the potential that the resultant velocities in the vicinity of the breach may be underestimated. This is not considered to be significant issue as all the areas around all of the breaches have been designated the maximum hazard classification and thus recommended for the greatest degree of caution.

Topographic Data

The topographic data used in the Bexley SFRA modelling was issued by the Environment Agency's Remote Sensing Team in Twerton. Null values in the LiDAR were removed by the Environment Agency Technical Staff. The LiDAR grid was re-sized to a 10m grid for use in the modelling process. This increase in grid resolution was required to facilitate practical model run times. A 10m grid resolution is considered to be appropriate for use at the strategic level.

Filtered LiDAR was used in the modelling process, this dataset has had buildings and vegetation removed from it. A bare earth surface model therefore provided the base of the TuFLOW simulations. Buildings and vegetation do provide some obstruction to flow, however the Environment Agency's guidance recommends that a structure is only a permanent barrier to flow if it had been designed for that purpose. The use of varying surface roughness values was used in the modelling to represent the resistance to flow offered by buildings.

Southern Outfall Sewer Culvert

The culvert passing under the Southern Outfall Sewer has a potentially significant influence on the propagation of flooding within the Thamesmead embayment. A detailed survey of the culvert dimensions was not available and so the dimensions were approximated through consultation with the Environment Agency[24]. It was agreed that all three of the culvert openings should be represented in the model as being the same size and that each was approximately a 2m by 2m box culvert. The invert levels of both ends of the culvert was set the same (-0.5m AOD) as no information was available to suggest that there is bed gradient in the culvert. Invert levels were inferred from an inspection of the LiDAR data. Culvert blockage was not accounted for, thereby allowing maximum connectivity between the divided sections of the embayment.

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[24] E-mail correspondence from Anthony Hammond – Flood Risk Mapping and Data Management 13/05/08

Baseline Model Parameters

Model Surface Roughness

The surface roughness of the model area was simplified into key landuses. These were identified as buildings, open water, channelled water and other model areas (which grouped roads, open areas and any remaining areas). The following Manning's Roughness values were used in order to quantify the energy lost by water when travelling over different surfaces. These are presented in Table G.2

Table G.2 Model Surface Roughness Values

Landuse	Manning's 'N' Value
Buildings	0.1
Open Water	0.01
Channelled Water	0.04
Other Model Areas	0.03

Topographic data

The model grid requires bridge decks and underpasses to be represented as flow routes as the LiDAR filtering process did not always open up these flow routes. The TuFLOW had to therefore incorporate "z point" correction layers to remove incorrect blockages to the propagation of flow. Table G.3 identifies the model files used to correct the topography.

Initial Water Levels

For the models at locations 8 and 9, an initial water level was set within the River Darent to mimic the tide locking of fluvial waters that may occur behind the tidal flood gate at the mouth of the Darent in the event of the gates being closed during an extreme tidal event. A conservative water level of 4m AOD was selected. For the overtopping scenario at location 10, the tidal defence gate is modelled as being open and therefore no tide locking is included.

Table G.3 Topographic Data and Mid/Mif References used in the TUFLOW Models.

	Locations 1 – 7	Locations 8, 9 and Overtop Location 10
Grid Size	10m	10m
Grid Extent	Bottom Left - TQ 431 777 Top Right - TQ 518 815	Bottom Left - TQ 513 745 Top Right - TQ 560 784
Origin of topographic Data	Greenwich SFRA – 1m filtered LiDAR	Howbury Project – 0.5m filtered LiDAR
Zpts derived from LiDAR	mi\2d_zpt_GW_10m.mid	mi\2d_zpt_HB_10m_DTM.mid
Changes to Z-pts		
Removing flow barriers and null values	mi\2d_zpts_TMEAD_LiDAR_fixv2.MIF	mi\2d_zpts_HB_LiDAR_fix.MIF
'Burning' in channels	mi\2d_zln_Fix_Watercourse.MIF	-
Redefining defences	mi\2d_zln_Defences_001.MIF	mi\2d_zln_HB_Defences.MIF
Landuse definitions	mi\2d_mat_GW_002_buildings3.mif mi\2d_mat_GW_001_water.mif	mi\2d_mat_HB_001.mif
Initial water levels	-	mi\2d_iwl_HB_003.MIF

Hydraulic Boundaries

A model boundary was created for each of the simulations and was based upon the 7.5m AOD contour. This boundary remained beyond the extent of the modelled flooding. The boundary did not in any part influence the flooding extent. In addition to each of the hydraulic boundaries, it was also necessary to create a boundary for the tidal inflow hydrograph. This required the designation of a 'pooling' area in the Thames into which the inflow boundary ("HT line") would spill.

Hydrographs for the 1 in 200 year tide in 2005 was supplied by the Environment Agency for each of the Thames ISIS model nodes within the Bexley reach. The location of these nodes is presented in Figure G.2. These were scaled to the predicted peak 1 in 200 year tide level in 2107 which was also issued by the Environment Agency. Figure G.3 presents an example of the 2005 and 2107 tide level predictions for the 1 in 200 year tidal event at node 3.8.

Figure G.2 Location and Name of the Environment Agency's ISIS model of the Thames

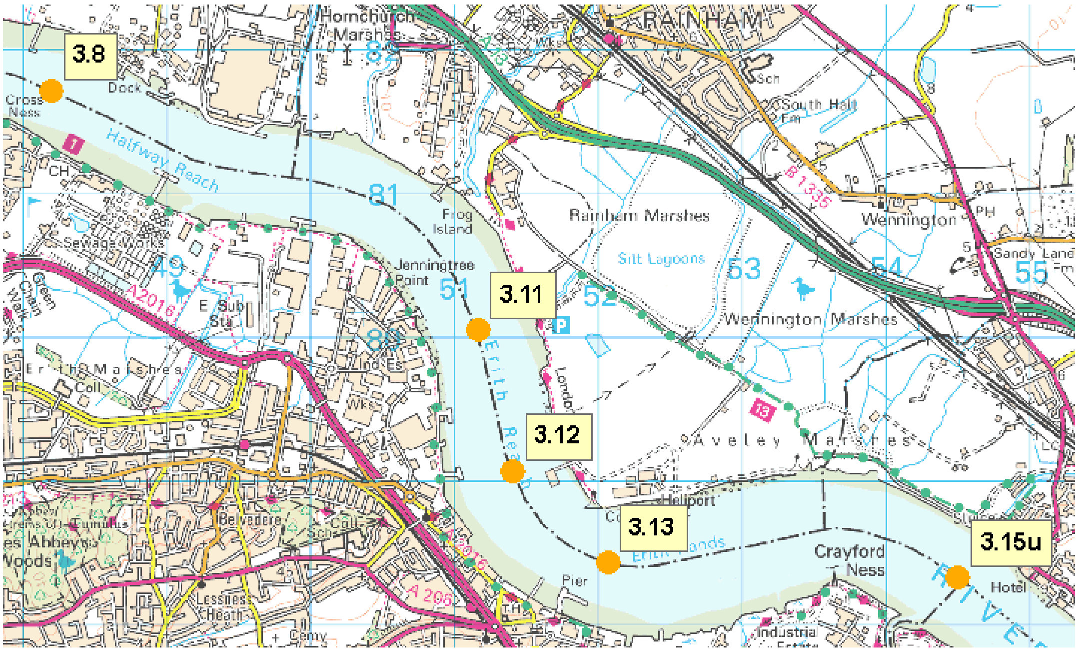
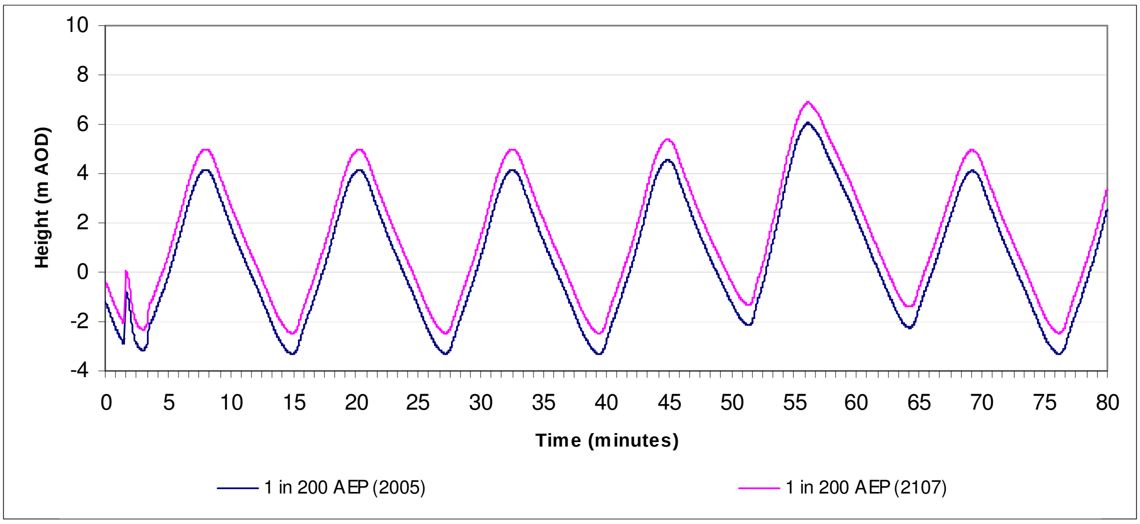


Figure G.3 The 2005 and 2107 Hydrographs for the 1 in 200 Year Event a at Node 3.8



1D Network - ESTRY

TUFLOW's 1-D ESTRY model was used for the representation of the culverts running through the Southern Outfall Sewer. A 1-D network was only included for breach locations 1 to 7. The MapInfo mid/mif file ***1d_nwk_GW_001.mif*** contains the 1-D network layout and is common throughout the simulations.

Simulation Specific Model Setup

The following tables present simulation specific model setup for each of the 10 model runs.

Table G.4 Breach Location 1 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 1 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_003_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table G.5 Breach Location 2 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 2 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_004_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	10 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table G.6 Breach Location 3 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 3 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_005_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	9.5 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

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Table G.7 Breach Location 4 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 4 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zln_BX_004_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.8 Breach Location 5 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 5 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_006_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	73.5
Timestep	2	**Approximate Run Time**	19 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table G.9 Breach Location 6 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 6 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zln_BX_006_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table G.10 Breach Location 7 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 7 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zln_BX_007_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table G.11 Breach Location 8 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 8 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zpt_HB_Breach_002.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	3	**Approximate Run Time**	1 hour
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table G.12 Breach Location 9 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 9 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zpt_HB_Breach_003.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	73.5
Timestep	1	**Approximate Run Time**	9 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

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Table G.13 Breach Location 10 – 1 in 200 year event including climate change (2107)

Simulation	Overtop Location 10 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zpt_BX_Breach_010.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40	**Model End Time**	73.5
Timestep	2	**Approximate Run Time**	7.5 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

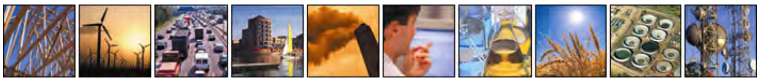

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Table G.14 – TuFLOW Model Setup File Names

Modeller	Breach	tcf	Location	tgc	Location	tbc	Location	bc_dbase	Results
Mark Bollaert	1	GW_0011.tcf	Bexley\Greenwich\Tuflow\Runs	GW_001.tgc	Bexley\Greenwich\Tuflow\Model	GW_001.tbc	Bexley\Greenwich\Tuflow\Model	Bc_dbase_GW_2107.csv	GW_0011.
Mark Bollaert	2	GW_0022.tcf	Bexley\Greenwich\Tuflow\Runs	GW_002.tgc	Bexley\Greenwich\Tuflow\Model	GW_002.tbc	Bexley\Greenwich\Tuflow\Model	Bc_dbase_GW_2107.csv	GW_0022.
Mark Bollaert	3	GW_0033.tcf	Bexley\Greenwich\Tuflow\Runs	GW_003.tgc	Bexley\Greenwich\Tuflow\Model	GW_003.tbc	Bexley\Greenwich\Tuflow\Model	Bc_dbase_GW_2107.csv	GW_0033
Mark Bollaert	4	BX_004_CC.tcf	Bexley\Greenwich\Tuflow\Runs	BX_004_CC.tgc	Bexley\Greenwich\Tuflow\Model	BX_004.tbc	Bexley\Greenwich\Tuflow\Model	Bc_dbase_BX_2107.csv	BX_004_CC
Mark Bollaert	5	GW_0055.tcf	Bexley\Greenwich\Tuflow\Runs	GW_005.tgc	Bexley\Greenwich\Tuflow\Model	GW_005.tbc	Bexley\Greenwich\Tuflow\Model	Bc_dbase_GW_2107.csv	GW_0055
Mark Bollaert	6	BX_006_CC.tcf	Bexley\Greenwich\Tuflow\Runs	BX_006_CC.tgc	Bexley\Greenwich\Tuflow\Model	BX_006.tbc	Bexley\Greenwich\Tuflow\Model	Bc_dbase_BX_2107.csv	BX_006_CC
Mark Bollaert	7	BX_007_CC.tcf	Bexley\Greenwich\Tuflow\Runs	BX_007_CC.tcf	Bexley\Greenwich\Tuflow\Model	BX_007.tbc	Bexley\Greenwich\Tuflow\Model	Bc_dbase_BX_2107.csv	BX_007_CC
Mark Bollaert	8	BX_8_HB_003_CC.tcf	Bexley\Howbury\Tuflow\Runs	BX_008.tgc	Bexley\Howbury\Tuflow\Model	BX_008.tbc	Bexley\Howbury\Tuflow\Model	Bc_dbase_HB_2107	BX_8_HB_003_CC
Mark Bollaert	9	BX_9_HM_007_CC_v3_Jan09.tcf	Bexley\Howbury\Tuflow\Runs	HB_009_v2_Jan09.tgc	Bexley\Howbury\Tuflow\Model	BX_009.tbc	Bexley\Howbury\Tuflow\Model	Bc_dbase_HB_2107	BX_9_HM_007_CC_v3_Jan09
Mark Bollaert	10	BX_10_CC.tcf	Bexley\Howbury\Tuflow\Runs	BX_010.tgc	Bexley\Howbury\Tuflow\Model	BX_010.tbc	Bexley\Howbury\Tuflow\Model	Bc_dbase_HB_2107	BX_10_CC