Level 2 Strategic Flood Risk Assessment
Technical Element

North Somerset Council

September 2009
Final Report
9T3624

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APPENDICES

1 INTRODUCTION

1.1 Commission award

Royal Haskoning were commissioned in April 2008 by North Somerset Council (NSC) to provide the technical information necessary to complete a Level 2 Strategic Flood Risk Assessment (SFRA) to meet the requirements of Planning Policy Statement 25: Development and Flood Risk (PPS25).

1.2 Background

Having commissioned Royal Haskoning to undertake a Level 1 SFRA across the North Somerset Local Planning Authority area, NSC identified the need for a Level 2 SFRA analysis at specific locations where there could be the potential to develop in areas at risk of flooding.

A Level 1 SFRA is required by PPS25 so that the risks of flooding can be understood before allocating land for development. PPS25 sets out a procedure called the Sequential Test which aims to ensure that land is allocated for development in lower flood risk zones in preference to high risk zones.

However, it is not always possible to allocate all proposed development and infrastructure in accordance with the Sequential Test for various reasons and it may be necessary to extend the scope of the SFRA. PPS25 therefore sets out another procedure called the Exception Test, which if passed means that development can take place in higher flood risk areas.

In order to undertake the Exception Test for specific locations as identified in the Level 1 SFRA, PPS25 requires quantifiable information regarding flood risk and possible mitigation measures to understand the flood risks at each site and the drainage requirements necessary. This is to assess whether it is appropriate for proposed development to take place. The technical information we provide will enable NSC to draft criteria based policies against which to consider planning applications for these sites. This will be done by outlining policies in the Level 2 SFRA that the supporting Flood Risk Assessments (FRAs) should adhere to in order to satisfy criterion (c) in paragraph D9 (The Exception Test) in PPS25; "a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall".

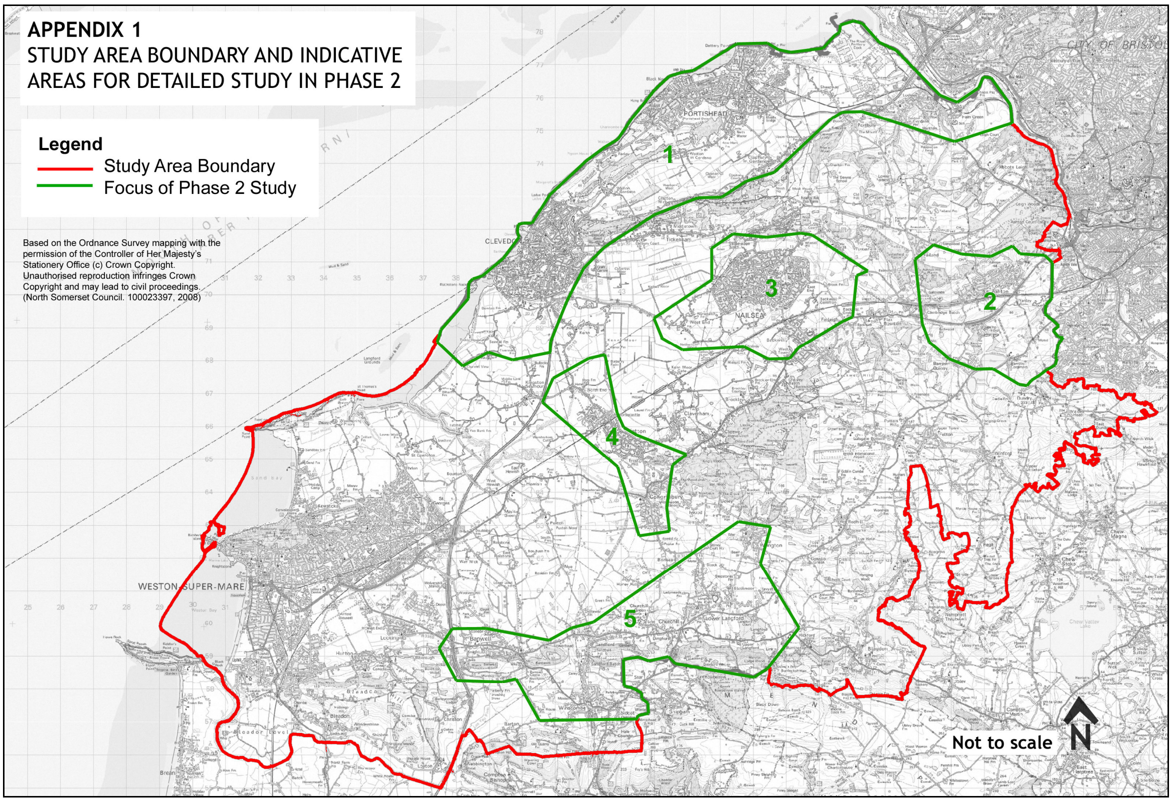
1.3 Study Area

This Level 2 SFRA focuses on locations where there is a need to consider additional development on land within existing flood risk areas or where development could increase run-off affecting existing floodplains and vulnerable land. These areas are shown on Figure 1.1 and comprise:

- Area 1: coastal strip from south of Clevedon to Ham Green
- Area 2: urban extension area south-west of Bristol
- Area 3: land around Nailsea and Backwell
- Area 4: land around Yatton/Congresbury
- Area 5: land around Banwell/Winscombe/Churchill/Wrington

Due to the low lying land of the Somerset Levels and potential threat of severe tidal inundation across NSC area, a third of the properties across the study area are located in areas at risk of flooding from both rivers and the sea. A location plan of the Level 2 study areas is given in Figure 1.1.

Figure 1.1: Level 2 study areas



This report will cover the SFRA Level 2 elements for all five areas shown in Figure 1.1. The analysis of flood risk at Weston-super-Mare is not included within this study and guidance regarding potential fluvial flood risk should be sought through the work undertaken for the Weston-super-Mare Flood Management Study Phase II: Options Report; *Royal Haskoning 2008.* There are also plans for a Weston-super-Mare Level 2 Strategic Flood Risk Assessment. Once produced, this will incorporate the most up-to-date modelling for the area.

1.4 Scope of Work

1.4.1 Overview

The Level 2 SFRA considers the beneficial effects of existing flood risk management infrastructure, such as raised defences, in influencing the extent and severity of flooding from rivers and the sea as compared to the Environment Agency Flood Zones. The increased scope of the Level 2 SFRA will enable the production of mapping showing flood outlines for different probabilities, impact, speed of onset, depth and velocity variance of flooding taking account of the presence and likely performance of flood risk management infrastructure.

The information will not be sufficient to be used to support individual planning applications; rather it will provide the background information necessary that FRAs can draw upon to support planning applications in the future. The information will also allow NSC to assess criterion c) of the Exception Test at a strategic level for the lifetime of a proposed development through the provision of detailed information on flood risk now and in 100 years time to account for climate change.

1.4.2 Assessment of flood probability, depth and velocity

Royal Haskoning have previously undertaken modelling studies on behalf of the Environment Agency for the tidal areas within NSC and we have obtained permission from the EA to use these models and the associated extreme tide level data. We have also obtained permission from the EA and Clarke Bond to use the existing models for the Congresbury Yeo and Ashton, Colliter's and Longmoor Brooks to assess the river geometry and maximum water levels to determine the probability for the onset of flooding. We have used 3D GIS techniques and LiDAR Digital Terrain Model (DTM) data to interpolate grid based maps of depth and velocity from the model outputs. This has been undertaken for current flood risk and also considers the impact of climate change on fluvial and tidal flood risk in 100 years time. Where existing models do not exist we have created a basic 1D model using the underlying topography derived from the LiDAR DTM data. A summary of the models used is given in Table 1.1.

Table 1.1: Summary of models used

Area	Location	Model used
1	coastal strip from south of Clevedon to Ham Green	Royal Haskoning TUFLOW (2D) model and Royal Haskoning Tidal B calculation software. NB: only tidal flooding assessed
2	urban extension area south-west of Bristol (Long Ashton)	Clarke Bond iSIS (1D) model (under review by Environment Agency)*
3	land around Nailsea and Backwell	Royal Haskoning HEC-RAS (1D) model. LiDAR based
4	land around Yatton/Congresbury	Jacobs TUFLOW (2D) model
5	land around Banwell/Winscombe/Churchill/Wrington	No modelling undertaken

*A model in this area is being used for a flood map challenge. The outcome of this Flood Map challenge was not available at the time of writing.

In order to estimate the 1 in 100 year fluvial flows (and other return periods), we have used the Flood Estimation Handbook (FEH), which is the Environment Agency approved method. At the strategic level we have not used observed data to improve flow estimates beyond those generated using catchment descriptors. We have undertaken the statistical analysis and the rainfall runoff or revitalised flood hydrograph method techniques where appropriate, and chosen the larger of the flow estimates derived from the two methods to follow a precautionary approach. An allowance of an increase in flows of 20% has been added to the estimate to account for climate change (fluvial), as required by PPS25.

Extreme tide levels have been reproduced from the Report on Regional Extreme Tide Levels (Posford Haskoning 2003), which is the standard now used by the Environment Agency for extreme tide predictions in the South West Region. These extreme tide levels have then been updated to take account of sea level rise for up to the next 200 years in order to undertake analysis of the effects of climate change. This has been carried out with reference to the Defra FCDPAG3 Economic Appraisal Note to Operating Authorities – Climate Change Impacts October 2006. In accordance with the PPS25 Practice Guide, residential developments should be considered for a lifetime of 100 years and commercial developments for 60 years.

The scope of this study does not cover groundwater or surface water flooding, which were assessed as part of the North Somerset Council Level 1 SFRA; *Royal Haskoning 2009*.

1.4.3 Verification of Defences and Areas Benefiting from Defences (ABDs)

Information about existing defences has been taken from the National Flood and Coastal Defence database (NFCDD). The Standard of Protection of existing defences has been verified with Environment Agency staff and the model geometry adjusted to ensure that the correct defence heights are represented within the models used. We have also identified the owners and maintainers of these defences.

Where raised defences are present flooding scenarios will take account of the 'with defences' and 'without defences' scenarios as it is possible to remove defences from the model geometry. Using these modelling results we will also make an assessment to determine broad scale defended area as required by the Environment Agency to show where flood defences provide protection to a 100 year standard (fluvial). This is primarily to identify residual risk areas to further emergency planning or future defence enhancements.

1.4.4 Impact of flooding: Flood Risk to People

Using the depth and velocity information we have determined and categorised the flood hazard for the current situation. The assessment of flood hazard follows the guidance as set out in technical report FD2320 and has been assessed for the 1 in 100 year (fluvial) event defended situation and the 1 in 200 year (tidal) event defended situation (2008 water levels). We have also made an assessment of the likely speed of onset of flooding which can be used to inform flood warning procedures and guidelines.

2 SITE SUMMARIES AND RECOMMENDATIONS

The modelling results presented in Sections 3 to 6 of this report and summarised below should not be used outside the realm of assessing the feasibility of sites for development allocation at a high level. Detailed site-specific assessments would have to be made to accompany planning applications for development taking into account for example local soil and topographic conditions, local rainfall intensity values and the density of the planned development. Appendix A contains guidance for site specific FRAs, the use of SUDs techniques and Flood Resilient Construction. This includes a decision tree for the planning process for Flood Risk Assessment that can be used as a check for North Somerset Council planners that all necessary stages have been followed.

2.1 Overview of flood risk and inundation

2.1.1 Area 1: coastal strip from south of Clevedon to Ham Green

Flood risk due to failure of defences is a significant potential issue for Area 1 with almost a third of the area in the 1 in 200 year tidal flood extents for the undefended situation. Whilst we have not investigated fluvial flooding as part of this study it should be noted that the tidal flood extents dominate any fluvial flood extents within Area 1 as defined by the Environment Agency Flood Zone 3 mapping. The flood risk is greatest in the north of the area at Portbury Dock where defences are overtopped at the 1 in 5 year return period, based on model results. Therefore we would recommend that if significant developments are put forward the existing defences will need to be accessed for their existing standard of protection and improved as required. See Section 4.2.1.

Without further improvements to the standard of protection of the defences we would recommend that the area at Portbury Dock be promoted for amenity, recreational or water compatible development in accordance with the Sequential Test in PPS25.

Flood depths can reach up to 3.2m at the 1 in 5 year event (rising to 3.7m at the 1 in 200 year event) which, regardless of the velocity of the flood waters makes the degree of flood hazard extreme, with danger for all including the emergency services. Any areas where the flood hazard risk is significant or extreme should consider appropriate warning mechanisms for the general public who may access these areas.

2.1.2 Area 2: urban extension area south-west of Bristol

Along the Ashton Brook flooding is minimal for all return periods.

Flooding along the Longmoor and Colliters Brooks starts to occur at the QMED event but does not become significant until the 1 in 20 year event between the Longmoor and Colliters Brooks in the north of the area. The potential area of flood risk falls within part of the south-west urban extension to Bristol, with flood depths generally less than 1m but increasing to 1.5m at the 1 in 100 year event in areas to the east of the Colliters Brook. We would recommend that this area be promoted for amenity and recreational use within the wider development area to retain the existing flood volume storage which this site provides. Allowances should also be made for an additional 5% -11% percentage run-off within the Ashton and Colliters Brook catchments to account for this potential development. Development of these flood vulnerable areas will lead to displacement of flows elsewhere within the catchment and may compromise any existing flood mitigation measures.

The Longmoor Drain outfalls to the River Avon. During high tides this can cause tide-locking of the drain and therefore increase the flood risk to the area, although this is generally more of an issue in the Lower Ashton Vale area.

2.1.3 Area 3: land around Nailsea and Backwell

There are numerous locations to the north, east and south of Nailsea where out of bank flow occurs during a QMED (50% AEP). There are limited extent changes for each return period and as a result there are only marginal increases in the extents of flooding for the flood return periods through to 1 in 100 year (1%). The majority of the flood waters for all return periods are generally relatively shallow with depths of up to 1m, however there are localised areas where flood water pools to reach depths in excess of 2m. Any areas where the flood hazard risk is significant or extreme should consider appropriate warning mechanisms for the general public who may access these areas.

No major development allocations are proposed within Area 3 but potential development of any of these flood vulnerable areas will lead to displacement of flows elsewhere within the catchment and may compromise any existing flood mitigation measures. Development is therefore likely to be restricted to infill within the existing Flood Zone 1 locations.

2.1.4 Area 4: land around Yatton/Congresbury

Flooding to the south-east and north-west of Congresbury is widespread at the 1 in 5 year event with minimal increases in extent by the 1 in 100 year event. To the west of Yatton the onset of flooding occurs slightly later at the 1 in 25 (4%) year event again with small increases in extent for increasing return periods. Flood depths are generally significantly below 0.5m for the low return periods leading to a moderate flood hazard but there are areas of localised depth increase up to 2m where the hazard becomes extreme regardless of the velocity of flood waters. Any areas where the flood hazard risk is significant or extreme should consider appropriate warning mechanisms for the general public who may access these areas.

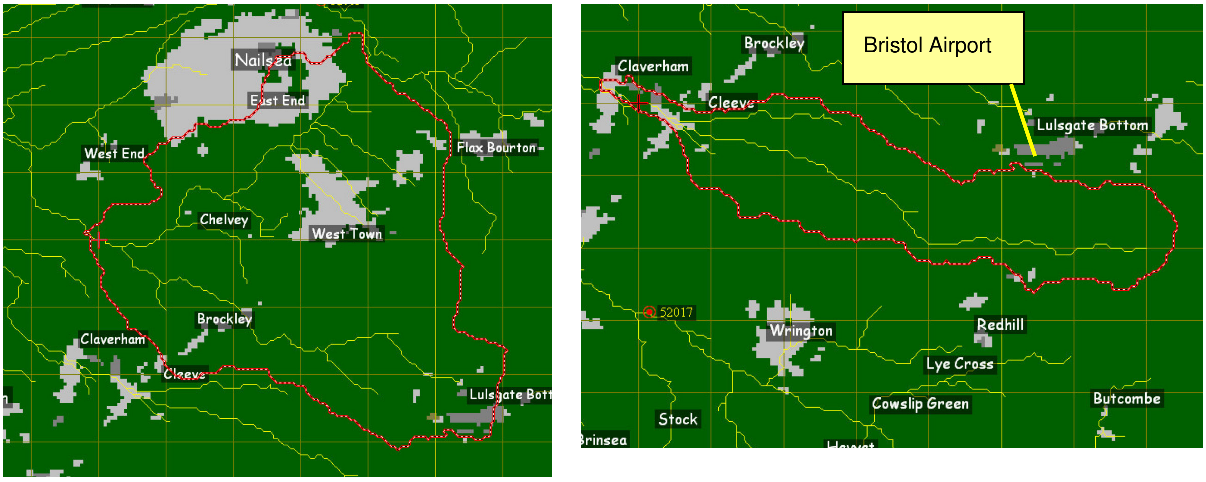
No major development allocations are proposed within Area 4 but potential development of any of these flood vulnerable areas will lead to displacement of flows elsewhere within the catchment and may compromise any existing flood mitigation measures. Development is therefore likely to be restricted to infill within the existing Flood Zone 1 locations.

2.1.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

Flood risk has not been modelled within this area for the reasons given in Section 3.3.5. Given the frequency of flood events within some of the catchments in this area such as Wrington we would recommend that an integrated urban drainage approach is undertaken in order to understand the flood risk comprehensively. This would allow for the complexities of the interactions between surface water flows, existing fluvial systems (that are extensively culverted in part) and a system of storm drains and combined sewers to be modelled in detail to assess potential mitigation options to the current levels of flood risk.

No major development allocations are proposed within Area 5 but potential development of any of these flood vulnerable areas will lead to displacement of flows elsewhere within the catchment and may compromise any existing flood mitigation measures. Development is therefore likely to be restricted to infill within the existing Flood Zone 1 locations. A 5% expansion to the southern side of Bristol Airport (9 hectares) will lead to additional flows to two catchments as identified by the Flood Estimation Handbook. These catchments (red dotted outlines) are shown in Figure 1.2 and both drain to the east of the airport towards the River Kenn and not to the south into Area 5.

Figure 1.2: Catchments draining the proposed 9 hectare Bristol Airport Extension



2.2 Surface water drainage

The hydrology assessments undertaken for the catchment area have been derived from Flood Estimation Handbook (FEH) catchment characteristics and where large scale development is proposed would have assumed that run-off from these proposed areas is based on greenfield runoff estimations. Following development of the site the increased impermeability will lead to an increased volume and run-off duration. Surface water flooding is difficult to predict and frequently develops quickly. For new developments, the best way of avoiding and managing surface water flooding if the development cannot be located away from the flood risk area through application of the Sequential Test, is to manage the water at source through Sustainable Drainage Systems (SuDS).

SuDS are designed to mimic natural drainage processes, along with treating the water to reduce the amount of pollutants getting into the watercourse. They can be located as close as possible to where the rainwater falls (at 'source') and provide varying degrees of treatment for the surface water, using the natural processes of sedimentation, filtration, adsorption and biological degradation. Guidance about the use of SUDS techniques can be found in Section 4.3 of the North Somerset Level 1 SFRA and has also been appended to this report (see Appendix A). SuDS can also bring environmental, ecological and social benefits to residents and users of developments, ensuring a commitment to criterion a) of the Exception Test to "...demonstrate that the development provides wider sustainability benefits to the community that outweigh flood risk."

Surface water drainage systems generally have an infiltration capacity based on a 30 year design storm and therefore care should be taken when assessing the interaction of flood extents for a 1 in 100 year event with potential surface water drainage systems. The development of Surface Water Management Plans (SWMPs) is being explored by the Government as part of the Water Strategy Future Water (Defra 2008). They will focus on managing flood risk and optimising the provision of SuDS and are envisaged to inform Local Planning Authorities in their preparation of Core Strategy documents, allowing appropriate policies on flooding and surface water drainage to be incorporated. We would recommend that a Surface Water Management Plan (SWMP) be considered for any infill development at Wrington within Area 5.

The effect of infill developments on existing urban areas such as Nailsea (Area 3), Yatton and Congresbury (Area 4) should be considered within the context of surface water management. However we do not believe the incidents of surface water flooding to be significant enough to warrant the preparation of a SWMP within these areas. NSC should seek to develop a flood risk management policy for infill development within areas prone to surface water flooding.

Major developments are proposed under the Local Development Framework within Areas 1 and 2. Within Area 1 residential development is planned covering an area of 0.6km^2 at Portbury Wharf and adjacent to the existing Portishead marina. As well as proposed infill there are also residential developments planned to the southwest of Portishead at Charlcombe Wood and to the south east at Moor Farm. A railway station is also proposed north of Easton-in-Gordano adjacent to the Royal Portbury Dock complex. Within Area 2 proposed developments cover 3 km^2 include the south-west urban extension to Bristol and redevelopment of the Barrow Hospital. Redevelopment of the Long Ashton Research Centre to the west of Long Ashton has also been undertaken.

Assessment of the impact of development within Area 2 on percentage runoff using the Wallingford procedure has identified a 5-7% increase in percentage runoff across the Ashton Brook catchment and up to 11% across the Colliters Brook catchment. Within Area 1 the additional runoff from the proposed 0.6km^2 of residential development falls within the tidal flood area extents and drainage works should consider the diversion of additional surface water flows to tidal outfalls with development design preventing the movement of flows inland.

2.3 Consequences of infilling flood plain

Areas within the site which are designated as Flood Zone 3b (Functional Floodplain) and Flood Zone 3a are discussed in Section 3.3.6. Following the PPS25 Sequential Test, the allocations of residential dwellings can be classified as More Vulnerable. Development of More Vulnerable allocations is not permitted within Flood Zone 3b and the Exception Test is required to allow for development within Flood Zone 3a. The provision of Essential Infrastructure such as highway routes to allow for evacuation of the site, is permitted within both Flood Zone 3a and 3b providing the Exception Test can be satisfied. Public Open Space is designated as Water compatible development and therefore development is appropriate within all Flood Zones. Commercial operations requiring waterside locations such as docks, marinas and wharves are also classified as water compatible developments.

Under a fluvial or tidal event, the effects of raising land for development in order to mitigate flood risk, could increase flood risk elsewhere. At a local level, under any flooding scenario, raising the ground levels may change the direction of flow. We recommend that the impact of raising ground for development is considered within site-specific flood risk assessments. This requires a reasonably accurate development Masterplan layout of the site, with estimated build and landscaping elevations detailed. An assessment of the consequences of infilling of the flood plain is a requirement under criterion c) of the Exception Test- “a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and where possible, will reduce flood risk overall” and should be undertaken as part of the detailed site specific Flood Risk Assessment.

2.4 Adequacy of existing defences (based on NFCDD data)

2.4.1 Area 1: coastal strip from south of Clevedon to Ham Green

The majority of the standard of protection offered along the coastline of Area 1 is sufficient to maintain a 1 in 200 year standard of protection. However at certain locations at Portbury Wharf only a 1 in 5 year standard of protection is currently provided. Consideration of the effect of increased flooding as a result of climate change needs to be considered by port operations within this area to determine the point at which further remediation works are required.

Whilst the risk of a breach appears to be low, the main flood risk is as a result of overtopping. While the defences offer a sufficient standard of protection for much of the coastal strip at present, we believe overtopping can occur too frequently at present to offer a satisfactory standard of protection at Portbury Wharf.

2.4.2 Area 2: urban extension area south-west of Bristol

Defences are not present within this area. Watercourses assessed as part of this study are mainly natural channels and along the Ashton Brook, flows are contained in channel for all studied return periods however at the convergence of the Longmoor and Colliters Brook the onset of flooding occurs at the QMED event.

2.4.3 Area 3: land around Nailsea and Backwell

Defences provide a varying standard of protection ranging from the QMED to the 1 in 100 year event. Where properties are present defences are generally at least at the 1 in 100 year standard of protection and therefore the majority of land vulnerable to flooding is agricultural. However there are a number of vulnerable existing properties to the north of Nailsea at Cradle Bridge and to the north of Backwell Common. It is unlikely that increasing the standard of protection of these defences will be economically viable (as there are not sufficient numbers of properties at risk) so properties at risk should seek to implement individual property protection measures. Should new development be proposed or planned current defences would not meet the requirements of criterion C of the Exception test.

2.4.4 Area 4: land around Yatton/Congresbury

The greatest impact of defences is apparent to the west of Congresbury where the risk of flooding is reduced from the 1 in 5 year event (without defences) to the 1 in 50 year event (with defences). The defences also produce significantly less flooding occurs for the 1 in 100 year event. The majority of land vulnerable to flooding is agricultural but properties are at risk to the south east of Congresbury where there are a number of short sections of defence at the 1 in 50 year standard of protection (within a section of 1 in 100 year standard of protection). Works therefore could be considered to improve these defences through the raising of the existing embankments. With the impact of climate change, the extent of inundation increases further and also properties become vulnerable to the west of Yatton signifying that works will be needed in the future to maintain the standard of protection for the expected level of flows up to 2085. Should new development be proposed or planned current defences would not meet the requirements of criterion C of the Exception test, and would need to be raised.

2.4.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

Defences are not present within this area.

2.5 Access and Egress

PPS25 states that development in flood risk areas should be protected from fluvial and/or tidal flood risk over the lifetime of the development (100 years for residential development and 60 years for commercial development). Access and egress routes should be above likely flood levels, and therefore access to any development sites should be considered with dry alternatives offered if appropriate to ensure safe access and egress for emergency vehicles and residents. Specific safe routes for access and egress should be identified as part of a site specific FRA.

Developments which include flood risk areas need to provide appropriate flood warning and emergency plans so that users and residents are safe should a flood occur. Flood warning systems (such as Flood Warnings Direct operated by the Environment Agency) should not be solely relied on as responses to flooding should also be a result of active planning. Planning conditions can be used to cover the maintenance of signs and keeping evacuation routes clear, details of which should be provided in a site specific FRA.

2.6 Potential mitigation and management of residual risk

Mitigation measures for development at any of these sites would need to be considered within a site specific FRA to demonstrate the site will be safe, without increasing flood risk elsewhere, and, where possible will reduce flood risk overall, therefore satisfying criterion c) of the Exception Test. The adoption of flood resilient design and construction, where appropriate, should also be included as part of the site specific FRA in order to satisfy the Exception Test and manage residual flood risk. Specific resilience measures that can be undertaken are detailed in Appendix A.

Even where a high frequency of flooding exists across the site sufficient economic benefit for the justification of further mitigation works needs to be identified in order to apply for Government funding. Further measures to manage residual risk could include the use of developer contributions towards flood mitigation schemes and the management of surface water discharge from the site. These contributions are normally achieved through Section 106 agreements implemented by the Local Planning Authority. Specific mitigation measures would be identified through a site specific FRA.

2.6.1 Area 1: coastal strip from south of Clevedon to Ham Green

Mitigation measures to protect against tidal flooding and the potential for surface water inundation at the Portbury Wharf and Portishead marina areas will need to allow for surface water discharge to the Severn estuary and therefore allowances should be made for the potential effects of sea level rise on gravity flow discharge which may exacerbate limitations to drainage capacity during potential periods of tide-locking.

2.6.2 Area 2: urban extension area south-west of Bristol

Allowances should also be made for an additional 5% -11% percentage run-off within the Ashton and Colliters Brook catchments when designing any mitigation measures to account for future developments. A potential flood storage area has been incorporated by the developer into the preliminary layout design of the south-west urban extension to Bristol and therefore the design standard volume needs to account for additional flows due to development and due to the impact of climate change.

2.6.3 Areas 3, 4 and 5

These areas are not subject to major developments (unlike Areas 1 and 2) and therefore development based potential mitigation of residual risks such as defences and provision of flood storage areas have not been considered. However, as stated in Section 2.2, NSC should seek to develop a flood risk management policy for infill development within areas prone to surface water flooding. This policy should also cover potential flood risks from fluvial, tidal and ground water flooding in case of future development taking place as a result of infill through the completion of site specific Flood Risk Assessments and a requirement for Sustainable Drainage Systems (SuDS).

A summary table setting out key elements for areas 1 to 5 can be seen in Section 7.

3 ASSESSMENT OF FLOOD PROBABILITY, DEPTH AND VELOCITY

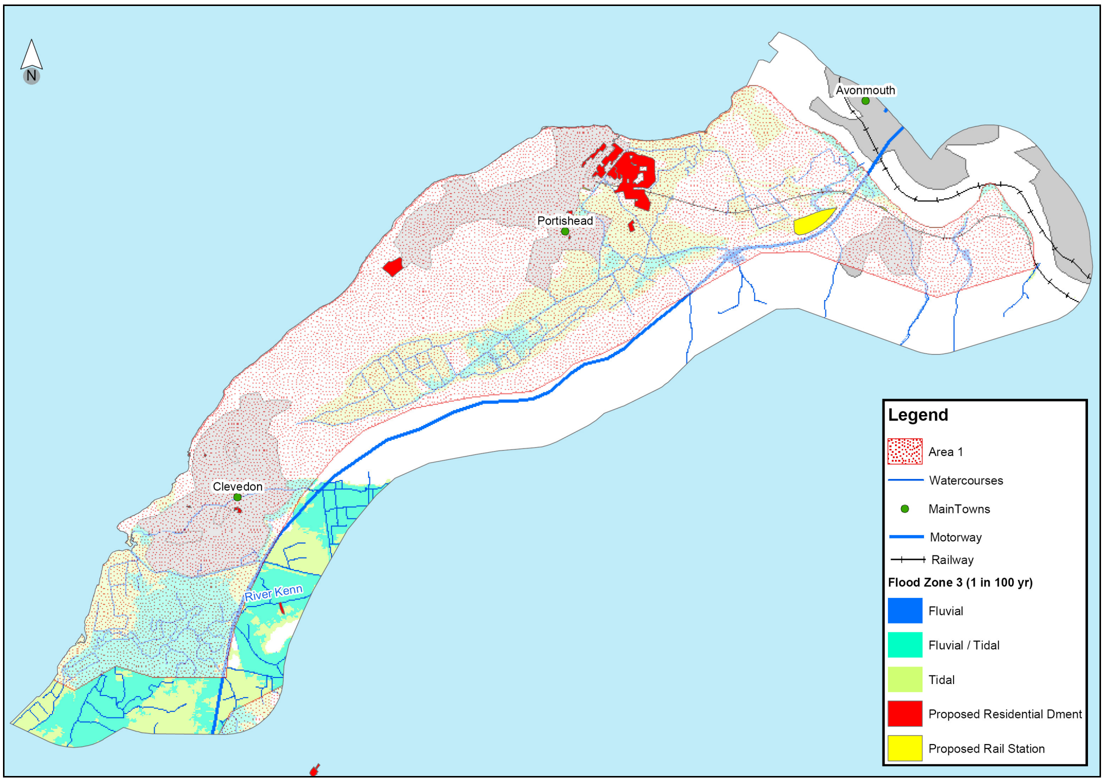
3.1 Catchment Overviews

3.1.1 Area 1: coastal strip from south of Clevedon to Ham Green

Portishead to Clevedon is a northwest facing coastline, lined with limestone cliff. Properties along this section of the coastline are generally sparse and located out of the floodplain. The cliffs are intersected by low lying alluvial areas such as Salthouse Bay. South of Clevedon, the coastline is comprised of low lying estuarine alluvium defended by a system of floodbanks with salt marsh in front of the raised defences. The area is mainly agricultural with associated small residential pockets.
Area 1 falls partially within the Portbury Ditch, River Kenn, Blind Yeo and Land Yeo catchments though the fluvial risk has not been assessed. This is due to the predominant nature of the tidal flood risk (which extends beyond the fluvial risk boundaries) and the locations of key development allocation sites in areas of tidal flood risk as apposed to areas of fluvial flood risk.

At Portbury Wharf and adjacent to the existing marina within Portishead extensive residential development is planned covering an area of 0.6km^2. As well as proposed infill there are also residential developments planned to the southwest of Portishead at Charlcombe Wood and to the south east at Moor Farm. A railway station is also proposed north of Easton-in-Gordano adjacent to the Royal Portbury Dock complex. An overview of Area 1 is shown in Figure 3.1.

Figure 3.1: Overview Map Area 1

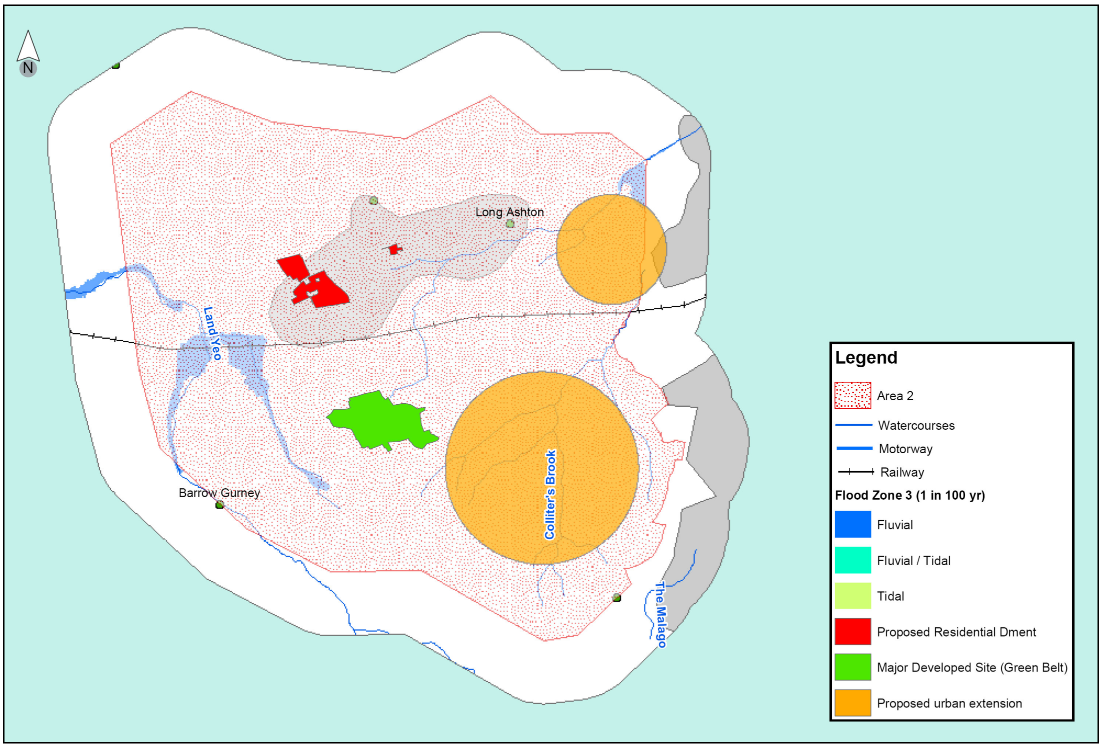


3.1.2 Area 2: urban extension area south-west of Bristol

Area 2 falls partially within the Portbury Ditch, River Kenn, Blind Yeo and Land Yeo catchments and partially within the Bristol Avon catchment. The watercourses that have been assessed within the Level 2 SFRA are the Colliters Brook and Ashton Brook which fall within the Bristol Avon catchment.

Within Area 2 there are a number of proposed residential allocations such as the south-west urban extension to Bristol, redevelopment of the Long Ashton Research Centre to the west of Long Ashton and redevelopment of the Barrow Hospital site. In total these developments cover approximately 3km^2. An overview of Area 2 is shown in Figure 3.2.

Figure 3.2: Overview Map Area 2

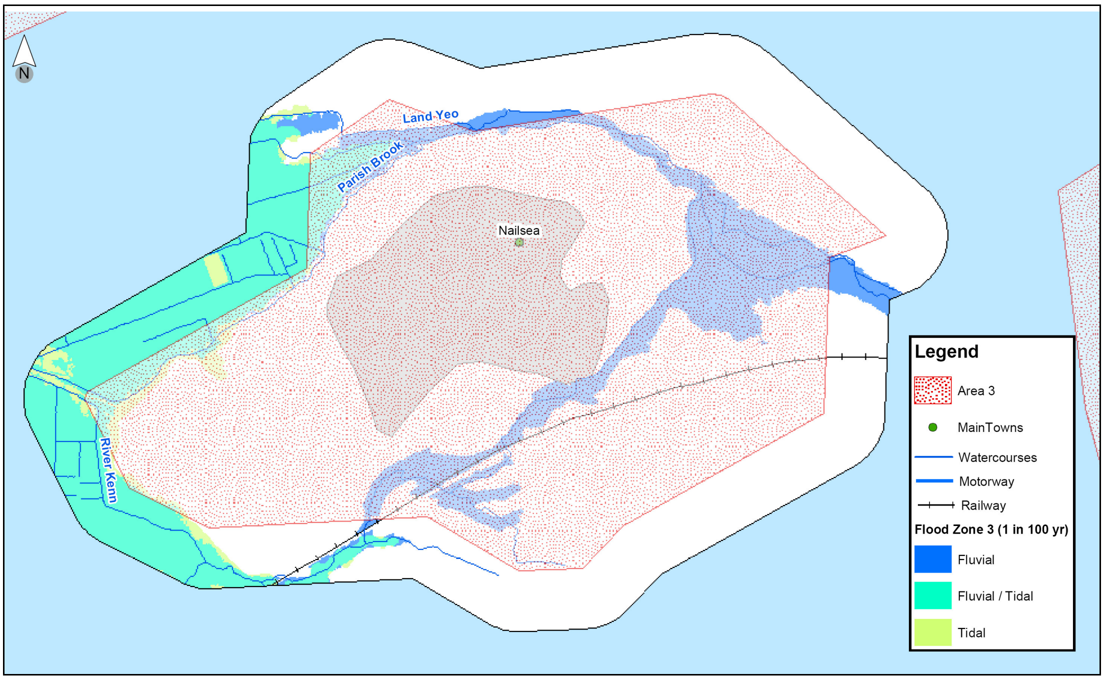


3.1.3 Area 3: land around Nailsea and Backwell

The Land Yeo watercourse issues west of Dundry village and flows approximately 7.5km west where two tributaries join the watercourse. The river then flows into area 3 where an un-named tributary flows south-west around the town boundary. The catchment is 7.3km^2 in size. The Land Yeo continues to skirt the northern edge of Nailsea and splits into four; Parish Brook, Blind Yeo, Land Yeo and Tickenham Drove Rhyne, and at this location the catchment is 25.6km^2. Each watercourse continues outside of the study area where the topography is low lying and there are a complex series of drains and ditches that drain the area as it flows towards the Land Yeo Outfall at Clevedon.

Incidents of flooding occurred in July 2006, January and July 2008 and are detailed further in the Level 1 SFRA. The information suggests that the cause of flooding is due to insufficient drainage and surface water rather than fluvial flows. There are no significant areas of proposed development within this area though infill development would be expected. An overview of Area 3 is shown in Figure 3.3.

Figure 3.3: Overview Map Area 3



3.1.4 Area 4: land around Yatton/Congresbury

The land encompassed by Area 4 primarily drains to the Congresbury Yeo catchment though the northern areas drain to the River Kenn and Blind Yeo catchments. The watercourse that has been assessed within the Level 2 SFRA is the Congresbury Yeo where a series of engineered structures control the flow. Up until 1940, when Phipps Sluice was constructed 7km downstream of the village, the river at Congresbury was tidal. In the 1970s the tidal limit was moved further downstream to Tutshill Ear to allow the M5 motorway to be built above high tide level. Following a report by Wessex Water (January 1981) a flood defence scheme was built at Congresbury to improve the standard of protection against fluvial flooding to between 1 in 50 and 1 in 100 years.

Small areas of residential development and infill are proposed within the north of Yatton and to the south of Congresbury. An overview of Area 4 is shown in Figure 3.4.

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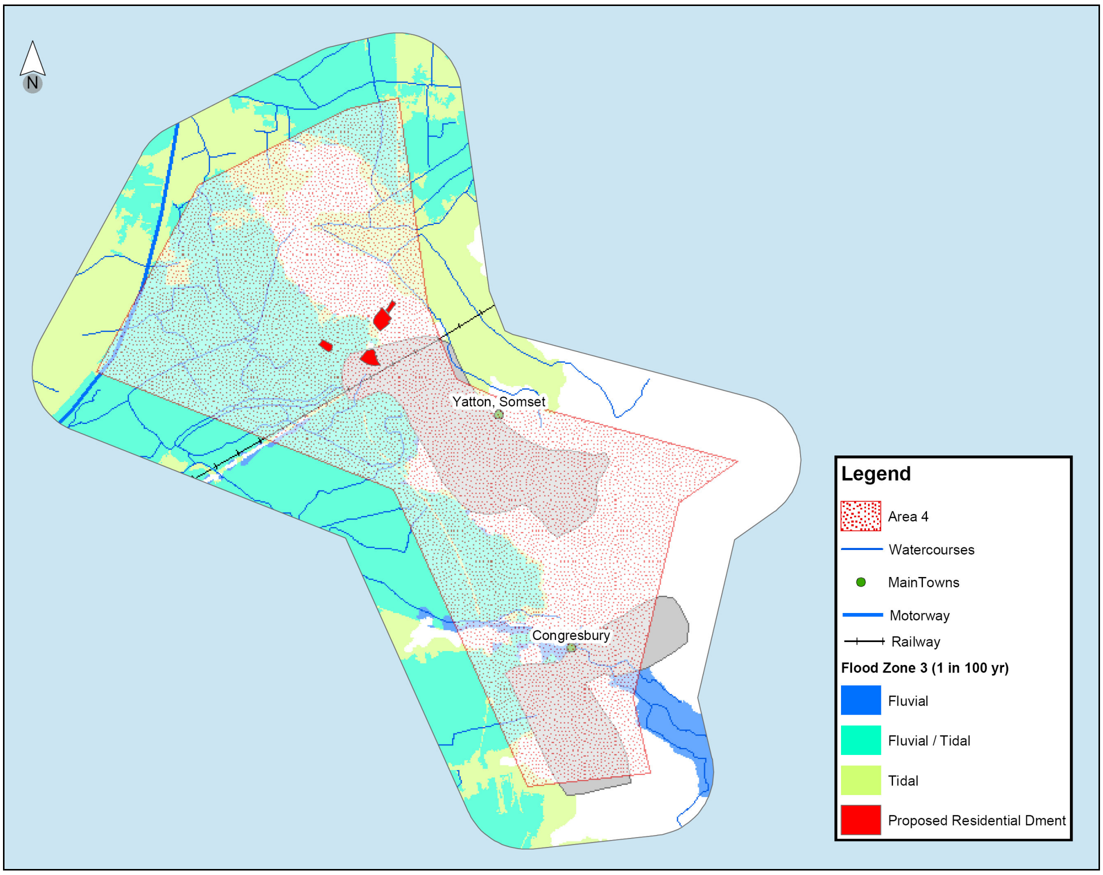
Figure 3.4: Overview Map Area 4

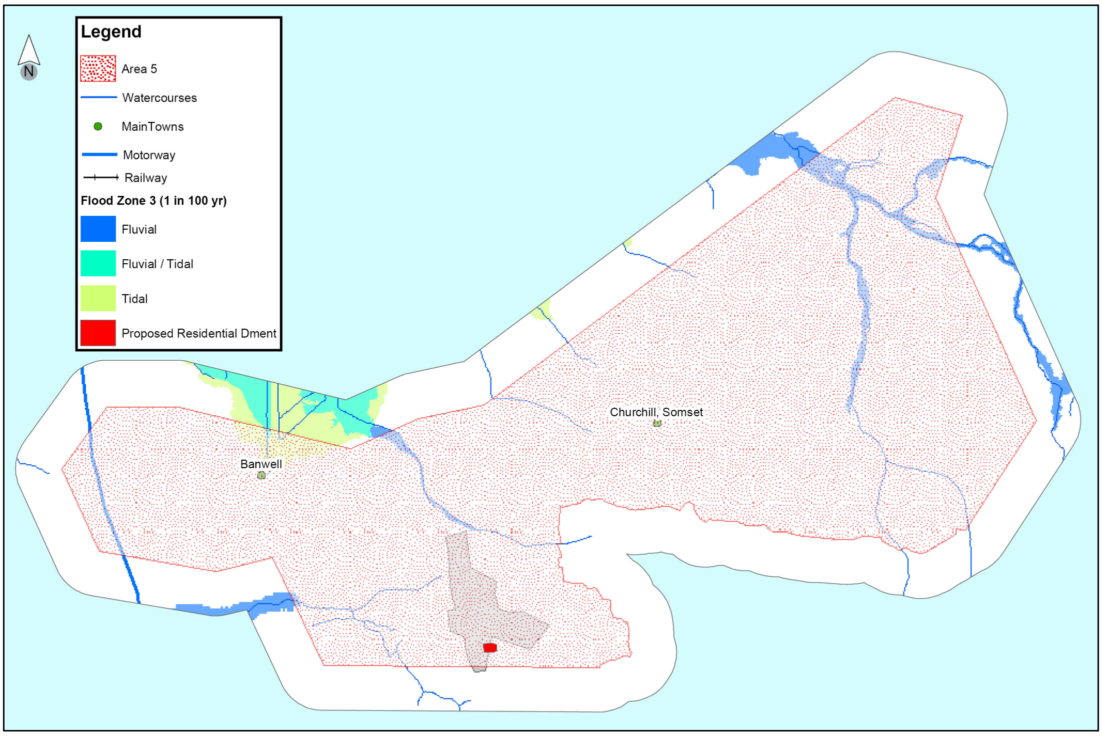


3.1.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

Area 5 drains to the River Banwell, Lox Yeo and Axe catchments and to a lesser extent the Congresbury Yeo. Approximately a third of the area is within a groundwater protection zone characterised by the relatively higher topography, and limestone and shale (lias) geology.

No major developments are planned within this predominantly rural area. An overview of Area 5 is shown in Figure 3.5.

Figure 3.5: Overview Map Area 5



3.2 Hydrological overview

3.2.1 Area 1: coastal strip from south of Clevedon to Ham Green

Extreme tide levels have been reproduced from the Report on Regional Extreme Tide Levels (Posford Haskoning 2003), which is the standard now used by the Environment Agency for extreme tide predictions in the South West Region. The tide levels are reproduced in Table 3.1.

The TUFLOW and TIDALB2 models were set up to run for 100 hours which equates to 8 tidal cycles, allowing for realistic time frames for large tidal swells to coincide with spring tides.

The extreme tide levels that were calculated by Royal Haskoning in 2003 have been extrapolated to take account of sea level rise for up to the next 200 years in order to undertake analysis of the effects of climate change. This has been carried out with reference to the Defra FCDPAG3 Economic Appraisal Note to Operating Authorities – Climate Change Impacts October 2006, which equates to the following net sea level rise allowances for the South West of England:

- 3.5mm per year for 1990 to 2025
- 8.0mm per year for 2025 to 2055
- 11.5mm per year for 2055 to 2085
- 14.5mm per year for 2085 to 2115

For reference, tides at Clevedon and Portbury Wharf (Avonmouth) are semi-diurnal i.e. comprising two high tides and two low tides each day.

Table 3.1: Extreme tide levels

	Clevedon		Avonmouth	
Tide Level	**Levels relative to Chart Datum (m CD)**	**Levels relative to Ordnance Datum Newlyn (m ODN)**	**Levels relative to Chart Datum (m CD)**	**Levels relative to Ordnance Datum Newlyn (m ODN)**
CDatum	0.0	-6.5	0.0	-6.5
1:1 yr	14.27	7.77	14.68	8.18
1:5 yr	14.49	7.99	14.92	8.42
1:10 yr	14.69	8.09	15.02	8.52
1:20 yr	14.77	8.27	15.20	8.70
1:50 yr	14.88	8.38	15.31	8.81
1:100 yr	15.05	8.55	16.48	8.98
1:200 yr	15.16	8.66	16.59	9.09

3.2.2 Area 2: urban extension area south-west of Bristol

Prior to the construction of the iSIS hydraulic model, a detailed hydrological investigation was undertaken by Clarke Bond. This covered the Ashton Brook, Colliters Brook, Longmoor Brook and three minor tributaries. The model and associated hydrological information were obtained and utilised with permission from Clarke Bond consultants. The model and data were verified by the Environment Agency who recommended use of the Revitalised Flood Hydrograph Method (ReFH) for hydrological analysis at this location.

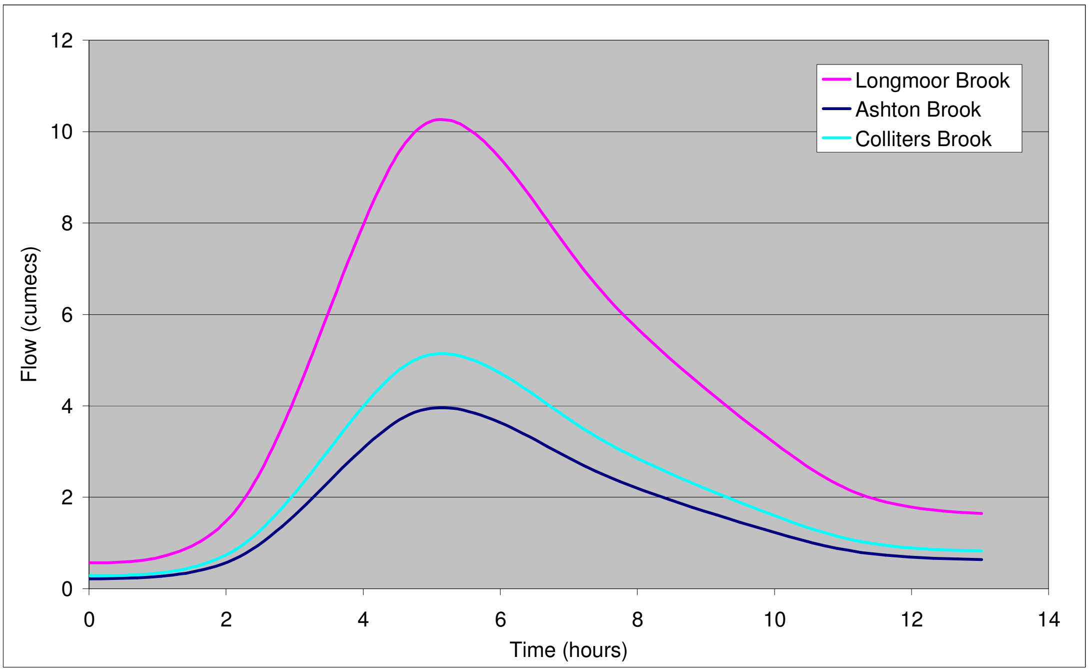
Catchment descriptors for the catchments were obtained using the Flood Estimation Handbook (FEH) CD-ROM version 1. The ReFH method was used to provide a realistic estimate of the flow for a range of return periods from the QMED event up to the 1 in 1000 year (0.1% Annual Exceedence Probability (AEP)) flood event.

The flows input into the model, as shown in Table 3.2 and Figure 3.6 were produced using the ReFH with observed data to improve the time to peak estimates. The three tributaries were included in the model however flows were very minor and are therefore not included in Table 3.2 or Figure 3.6.

Table 3.2: Area 2 Model inflows

Watercourse	Peak flow (cumecs)	
	QMED	**1 in 100 year**
Longmoor Brook	4.0	10.3
Ashton Brook	1.5	4.0
Colliters Brook	2.0	5.1

Figure 3.6: Longmoor, Ashton and Colliters Brook hydrographs
Area 2 100 year event model inflow hydrographs



In accordance with Annex B of PPS25, a climate change allowance of a 20% increase in flows was allowed. This is in line with the recommended sensitivity range for peak river flow for the period from 2055 to 2085.

3.2.3 Area 3: land around Nailsea and Backwell

Prior to the construction of the HEC-RAS hydraulic model, a hydrological investigation was undertaken. This covered the Land Yeo to ST 46673 171560, and the Eastern channel to ST 47603 69409. Catchment descriptors for each catchment were obtained using the Flood Estimation Handbook (FEH) CD-ROM version 1.

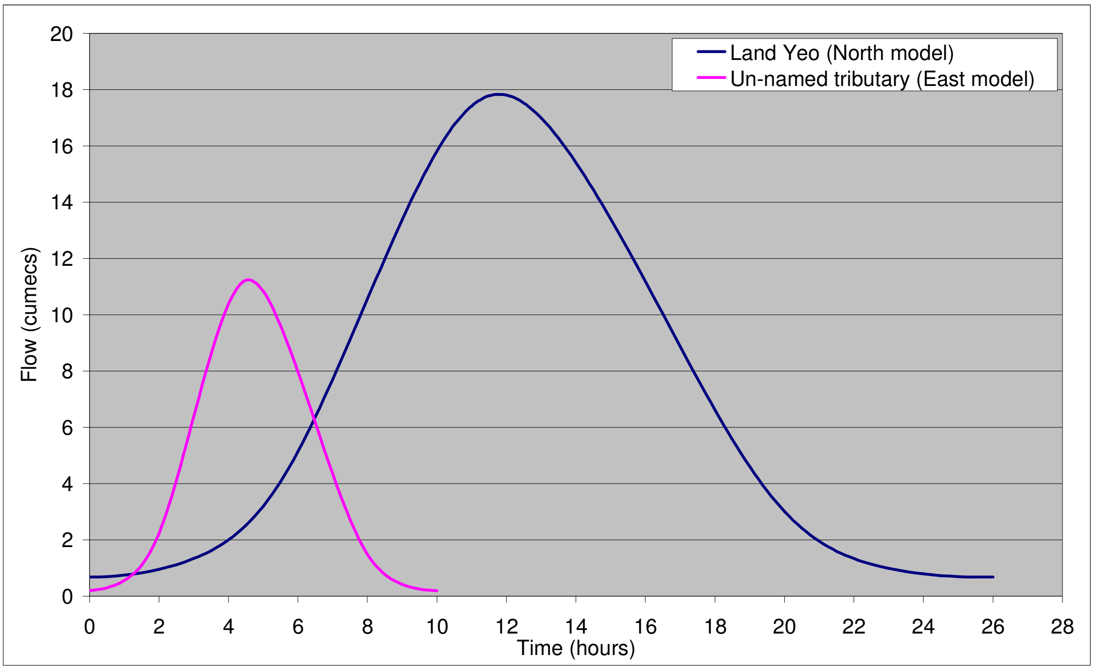
Two Environment Agency approved methods were undertaken to provide an estimate of the flow for a range of return periods from the QMED (50% AEP) event up to the 1 in 100 year (1% AEP) flood event.

Table 3.3: Area 3 Model Inflows

Watercourse	Statistical method		ReFH Rainfall runoff method	
	Peak flow (cumecs)		Peak flow (cumecs)	
	QMED (1 in 2.33 years)	1 in 100 year	QMED (1 in 2.33 years)	1 in 100 year
Land Yeo (Northern model)	3.4	8.8	5.3	17.8
Un-named tributary (Eastern model)	1.2	2.6	3.2	11.2

The flows input into the model, as shown in Table 3.3 and Figure 3.7, were produced using the ReFH method. Using these flows within the model produced the most realistic results with the closest alignment to the existing Environment Agency Flood Zone 3 (1 in 100 year extents).

Figure 3.7: Area 3 1 in 100 year event inflow hydrographs for Northern and Eastern models



In accordance with Annex B of PPS25 a climate change allowance of a 20% increase in flow was allowed. This was in line with the recommended sensitivity range for peak river flow for the period from 2055 to 2085.

3.2.4 Area 4: land around Yatton/Congresbury

Prior to the construction of the iSIS-TUFLOW hydraulic model, a detailed hydrological investigation was undertaken by Jacobs Babtie. This covered the Congresbury Yeo River taking account of the inflows from Blagdon Reservoir, Perry, Iwood, Row, Gooseum and Lower Yeo catchment areas. Catchment descriptors for the catchments were obtained using the Flood Estimation Handbook (FEH) CD-ROM version 1. Flows were determined for a range of return periods from the 1 in 5 year event (20% AEP lowest modelled event) up to the 1 in 100 year (1% AEP) flood event.

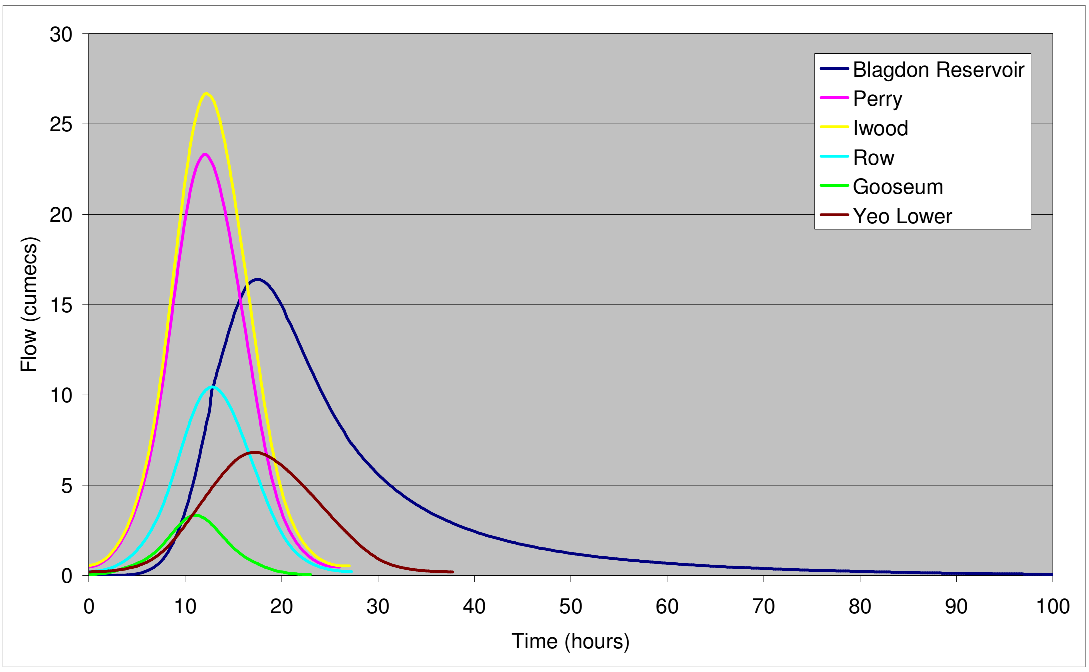
The flows input into the model, as shown in Table 3.4 and Figures 2.19, were produced using the ReFH with observed data to improve the time to peak estimates.

Table 3.4: Area 4 Model Inflows

Catchment	Peak flow (cumecs)	
	1 in 5 year	1 in 100 year
Blagdon Reservoir	6.1	16.4

Perry	11.2	23.3
Iwood	12.8	26.2
Row	5.0	10.4
Gooseum	1.6	3.3
Yeo Lower	3.4	6.8

Figure 3.8: Area 4 1 in 100 year event model inflow hydrographs



In accordance with Annex B of PPS25, a climate change allowance of a 20% increase in flows was allowed. This is in line with the recommended sensitivity range for peak river flow for the period from 2055 to 2085.

3.2.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

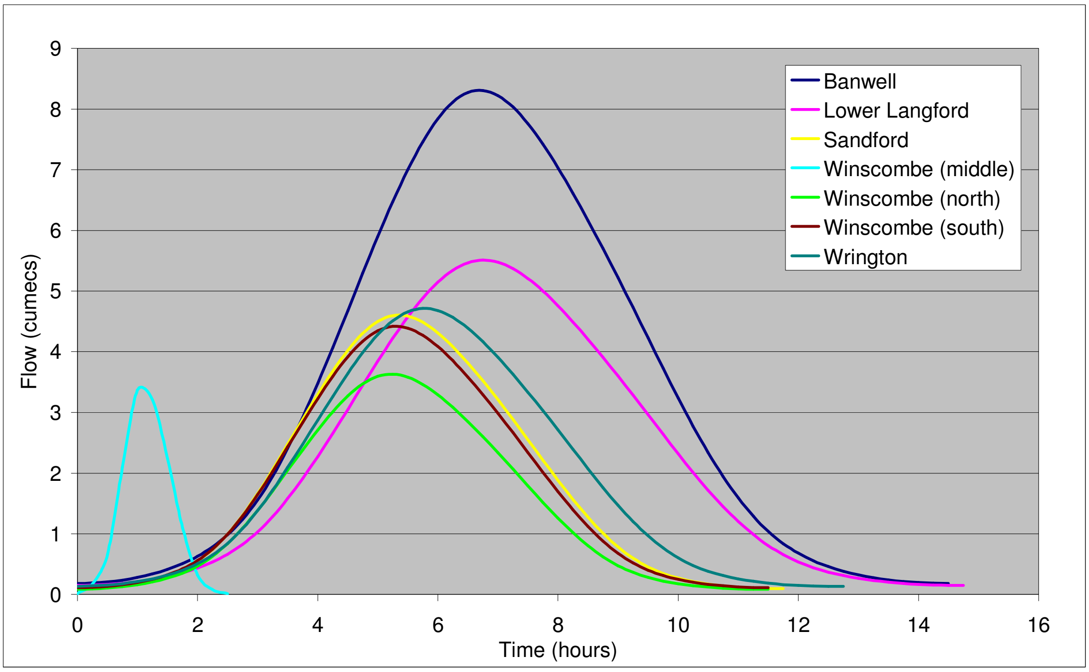
Whilst hydraulic modelling has not been undertaken for Area 5 a hydrological assessment has still been carried out. Flows for the Banwell, Lower Langford, Sandford, Winscombe and Wrington catchments were assessed using the Environment Agency approved ReFH method. This method was undertaken to provide a realistic estimate of the flow for a range of return periods from the QMED event up to the 1 in 1000 year (0.1% annual probability) flood event. In addition observed data was used to improve the time to peak estimates. The flows determined for Area 5 are given in Table 3.5 and shown in Figure 3.9.

Table 3.5: Area 5 ReFH flows

Catchment	**Peak flow (cumecs)**	
	QMED	**1 in 100 year**
Banwell	2.4	8.3
Lower Langford	1.5	5.5
Sandford	1.3	4.6

Winscombe (middle)	1.0	3.4
Winscombe (north)	1.0	3.4
Winscombe (south)	1.2	4.4
Wrington	1.3	4.7

Figure 3.9: Area 5 catchments 1 in 100 year event flow hydrographs



In accordance with Annex B of PPS25, a climate change allowance of a 20% increase in flows was allowed. This is in line with the recommended sensitivity range for peak river flow for the period from 2055 to 2085.

3.3 Flood Probability

For this section, flooding has been assessed for the 'without defences' scenario for all five areas. This follows the Environment Agency Flood Map (which is updated quarterly) depicting areas where there is a high risk (Flood Zone 3) or a low-to-medium risk (Flood Zone 2) of flooding from rivers and the sea. These zones do not take into account any flood defences that could reduce the impact of flooding if there was a flood event, because the defences can be breached, overtopped and may not be in existence for the lifetime of any development. Varying probability and return periods for flooding have been assessed to develop an indication of the increased severity of flood risk where appropriate as the probability of the event increases (becomes more likely) over time.

The effect of raised defences (present in Areas 1, 3 and 4 only) can be seen in Section 4.3 which includes figures of defended areas as a result of raised defences and descriptions as to the effect of defences on flood depth within these areas. Generally due to gaps or lower sections in the defences there is not a significant difference between the defended and undefended scenarios, which is another reason for mapping the undefended situation in these sections.

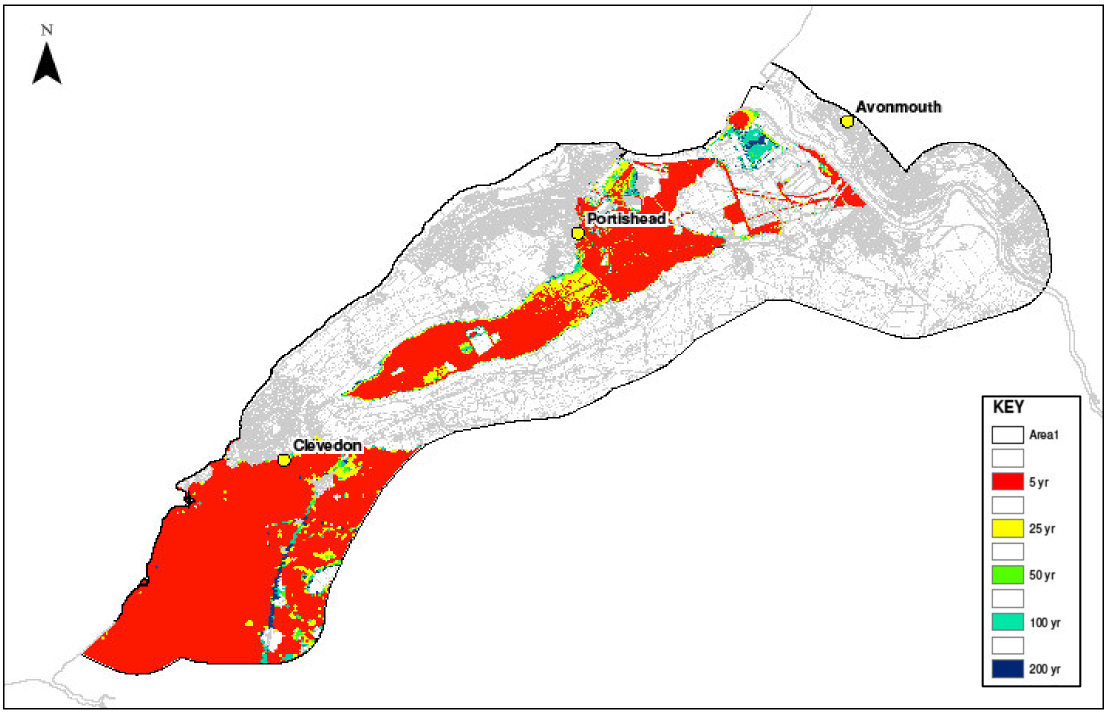
3.3.1 Area 1: coastal strip from south of Clevedon to Ham Green

Tidal flooding areas south of Clevedon were assessed using a TUFLOW model and the areas north of Clevedon to Ham Green (including Portbury Wharf) assessed using a TidalB Model. Runs for both models were based on the following events; 1 in 5 year return period (20% AEP), 1 in 10 year (10% AEP), 1 in 25 year (4% AEP), 1 in 50 year (2% AEP), 1 in 100 year (1% AEP) and 1 in 200 year (0.5% AEP).

Flooding was first indicated from the model results, south of Clevedon at the lowest modelled event (1 in 5 year) from tidal influences on the Blind Yeo and River Kenn. The extents affected in this region do not vary much in area between the 1 in 5 year (20% AEP) and 1 in 200 year (0.5% AEP) events and as such an increase in depth became more noticeable from the results.

Between Portishead and Ham Green, tidal flooding is indicated from the lowest modelled event, 1 in 5 year (20% AEP), to the west and south of the Royal Portbury Dock. The 1 in 5 year (20% AEP) event shows flooding extending landward in a south westerly direction to Walton in Gordano. Flooding is experienced at Clapton in Gordano from the 1 in 25 year (4% AEP) event, whilst flood waters are first experienced inside the Royal Portbury Dock at the 1 in 100 year(1% AEP) event. The tidal flood extents for Area 1 are given in Figure 3.10.

Figure 3.10: Area 1 Mapped flood extents (without defences)



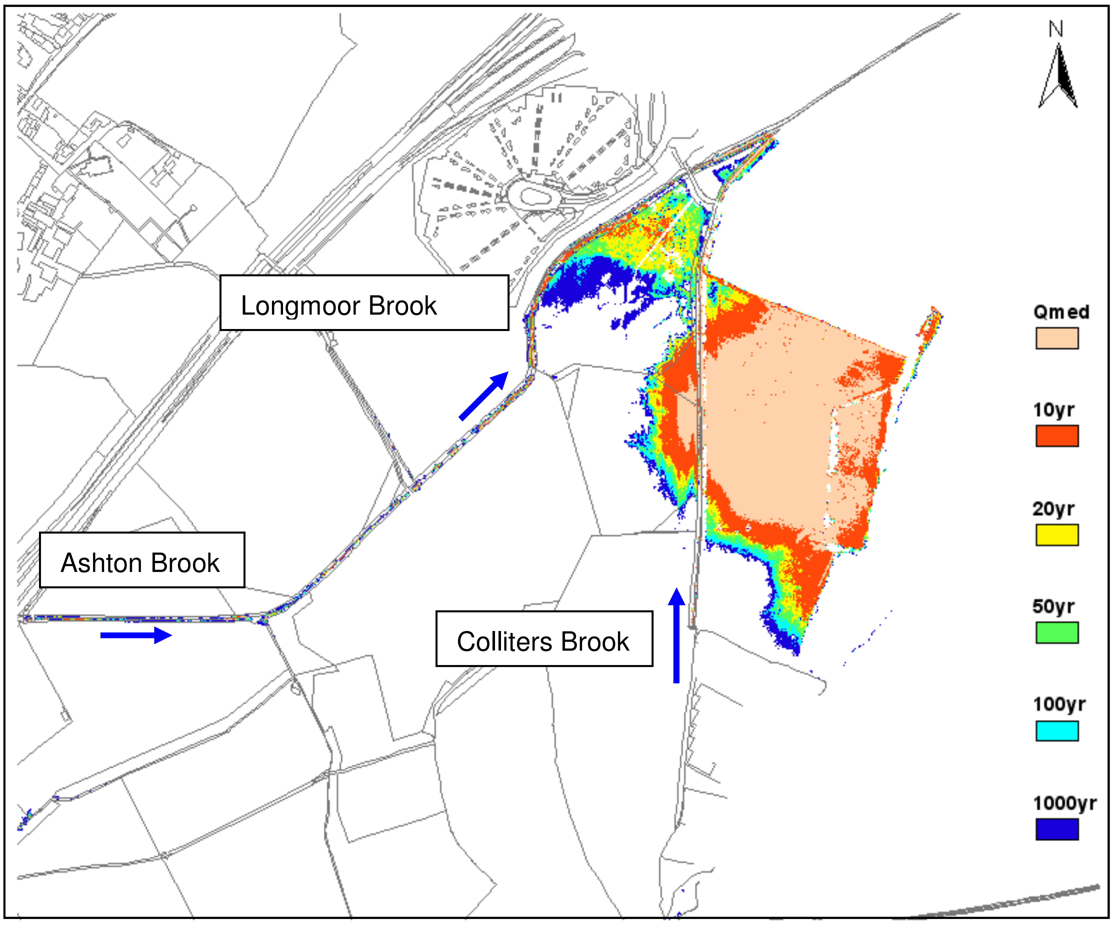
3.3.2 Area 2: urban extension area south-west of Bristol

The flood extents for the QMED (50% AEP), 1 in 10 year (10% AEP), 1 in 50 year (2% AEP) and 1 in 100 year (1% AEP) probability flood events derived from this model have been mapped using the LiDAR Digital Terrain Model (DTM) for the Ashton, Colliters and Longmoor Brooks and are given in Figure 3.11.

Along the Ashton Brook flooding is minimal for all return periods. Flooding along the Longmoor and Colliters Brooks starts to occur at the QMED event, extensively to the east of Colliters Brook, with some to the west of the brook. While the extents of the flooding increase for the 1 in 10 year event along Colliters Brook, flooding does not become significant until the 1 in 20 year event between the Longmoor and Colliters Brooks in the north of the area displayed in Figure 2.7.

The increase of extents for the 1 in 50, 1 in 100 and 1 in 1000 year events along Colliters Brook are not extensive. Similarly increases in extent pertaining to the land between the Longmoor and Colliters Brooks for the return periods 1 in 50 to 1 in 1000 year events, are also small with the exception of the 1 in 1000 year event which causes the flood extent to expand towards the south of this zone. Flooding is negligible for the south and east of the total area displayed in Figure 3.11.

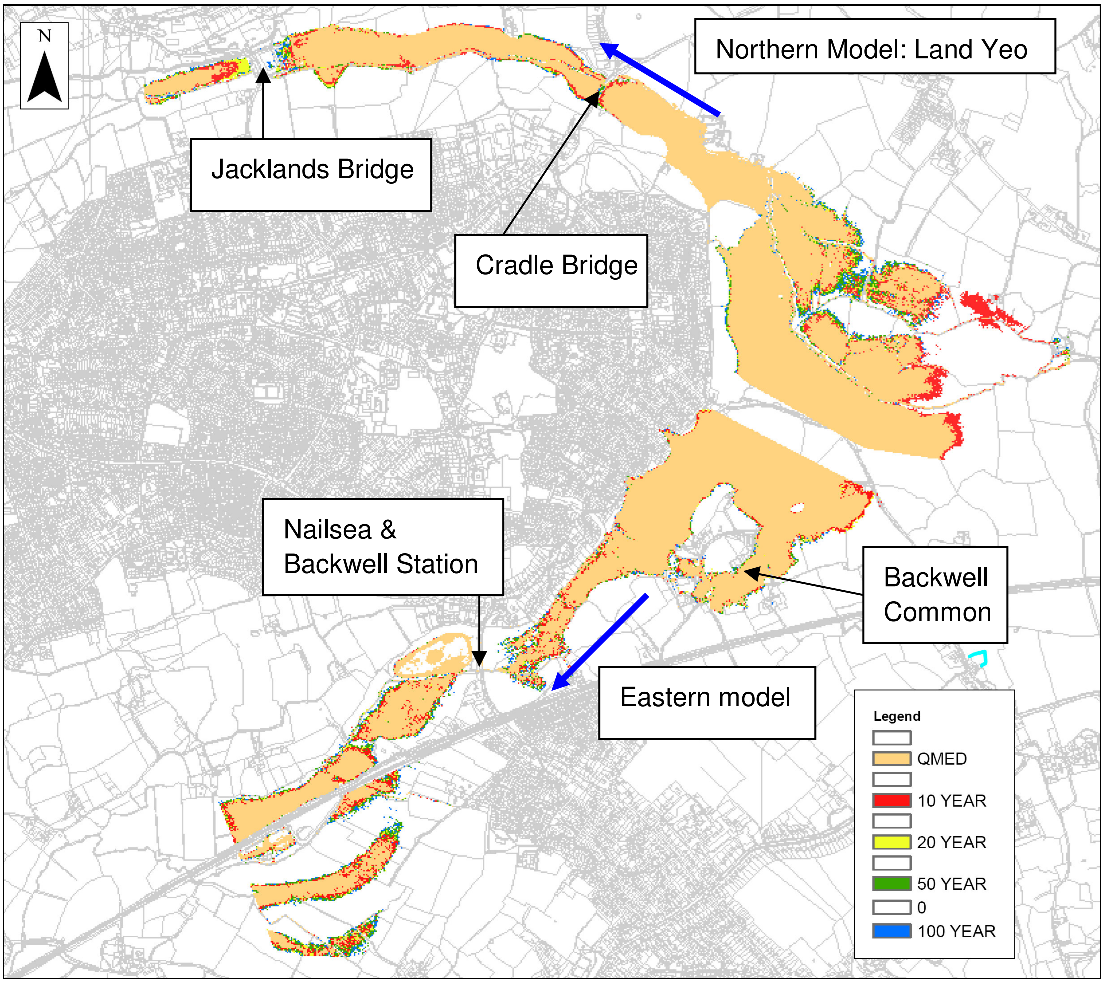
Figure 3.11: Area 2 Mapped flood extents (without defences)



3.3.3 Area 3: land around Nailsea and Backwell

Two models were built for Area 3. The northern model is of the Land Yeo and extends from Wamballs Wood in the east to Jacklands Bridge (347020, 171640). The Land Yeo tributary continues in a westerly direction and the second tributary, Parish Brook, flows southwest following the urban edge of Nailsea. Due to insufficient knowledge of the flow regime, structures and channel in this area it was not possible to accurately model the Parish Brook to its junction with North Drove Rhyne as this is a complex part of the watercourse. It was therefore necessary to stop the model at Jacklands Bridge where the model accurately represented the Land Yeo. The extents of flooding for both northern and eastern models can be seen in Figure 3.12.

Figure 3.12: Area 3 Mapped flood extents (without defences)



The eastern model covers an un-named tributary to the River Kenn and extends from just south of Brook Farm on Backwell Bow at the south east of Nailsea (upstream extent) to just upstream of Chelvey Court Farm which is to the north of the village of Chelvey.

Model runs using HEC RAS modelling software have been undertaken for the peak flow of the following events: QMED (50% AEP), 1 in 10 year (10% AEP), 1 in 20 year (5%

AEP), 1 in 50 year (2% AEP), 1 in 100 year (1% AEP) and 1 in 100 year (1% AEP) events. The flood extents for the flood return periods QMED through to 1 in 100 year (1%) from the HEC RAS model have been mapped using LiDAR DTM.

The areas identified to be at risk in the 1 in 100 year event are comparable to the EAs Flood Zone 3. The EA Flood Zone 3 shows extensive flooding throughout the low lying agricultural land surrounding Nailsea. The eastern outskirts of Nailsea are vulnerable to fluvial flooding and the western outskirts are affected by fluvial/tidal flooding.

There are numerous locations in the northern model where out of bank flow occurs during a QMED event (50% AEP) and therefore there are limited extent changes for each return period. As a result the flood extent boundary increases marginally from the QMED to the 1 in 100 year (1% AEP) event. As the Land Yeo flows downstream the extent of the flooding extends approximately 50m from the river on both banks at the QMED event (50% AEP).

For the eastern model the hamlet of Backwell Common is not affected by the QMED event and there are only marginal increases in the extents of flooding for the flood return periods QMED through to 1 in 100 year (1% AEP).

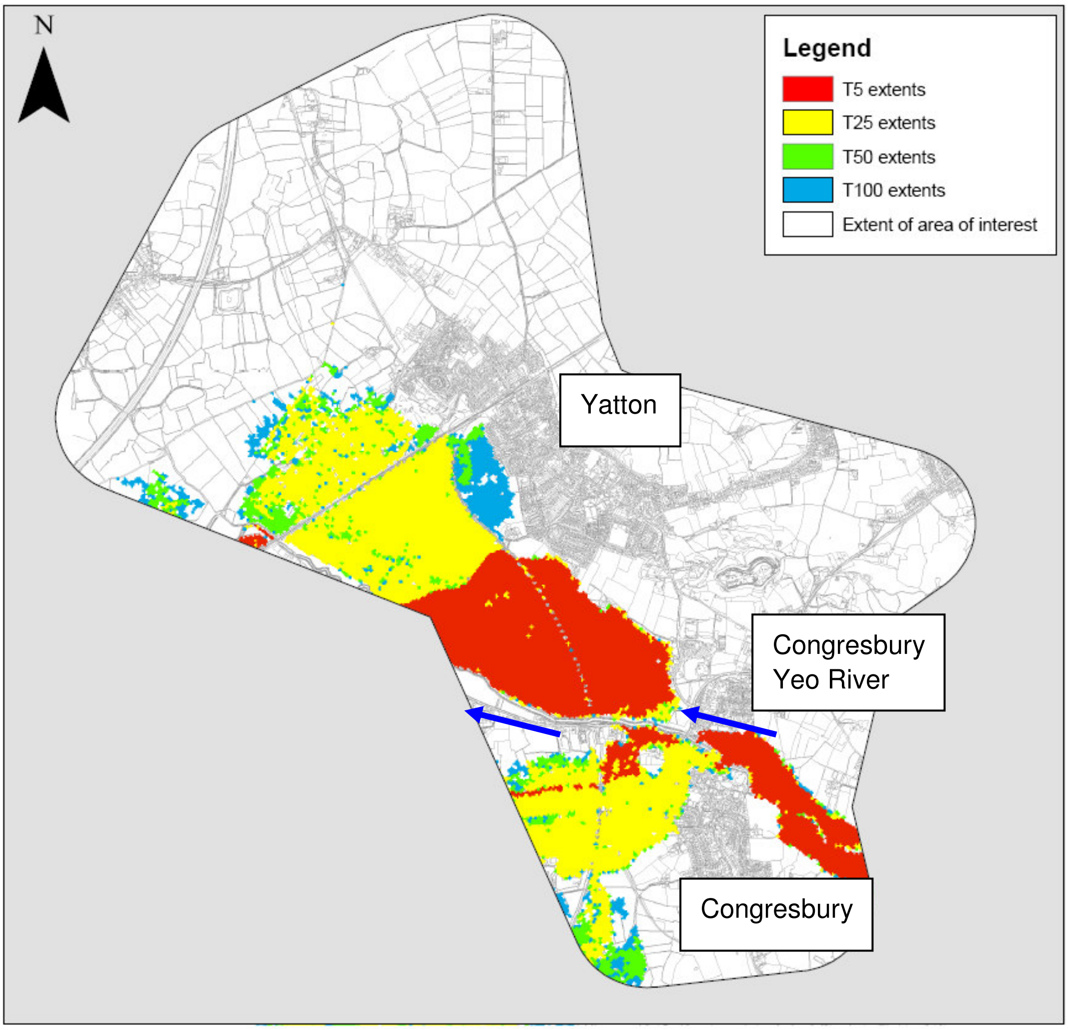
3.3.4 Area 4: land around Yatton/Congresbury

Model runs using TUFLOW modelling software have been undertaken for 1 in 5 year (20% AEP), 1 in 10 year (10% AEP), 1 in 20 year (5% AEP), 1 in 25 year (4% AEP), 1 in 50 year (2% AEP), 1 in 100 year (1% AEP) and 1 in 200 year (0.5% AEP) probability flood events. Tidal flooding in the area around Yatton and Congresbury starts to occur from the 1 in 5 year (20%) flood event. Extents of the flooding increase with the rise in return period of each event.

The flood extents for the 1 in 5 year, 1 in 10 year, 1 in 50 year and 1 in 100 year probability flood events derived from this model have been mapped using the LiDAR DTM for the area surrounding Congresbury and to the south of Yatton. Extents are displayed in Figure 3.13. The model extends further to the west and so only key results directly relating to Area 4 are shown.

Flood extents to the south-east and north-west of Congresbury are widespread at the 1 in 5 year event, however further increases with rising return period are minimal with very little increase in extent by the 1 in 100 year event. To the west of Yatton the onset of flooding occurs at the 1 in 25 (4% AEP) year event with small increases in extent by the 1 in 50 year event. Increases in extent are recorded to the west of Yatton for the 1 in 100 year event. West of Congresbury, flooding commences at the 1 in 5 year event with a significant increase in extent by the 1 in 25 year event. Further increases are indicated for the 1 in 50 year event only.

Figure 3.13: Area 4 Mapped flood extents (without defences)



3.3.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

The tidal flooding assessed using the TUFLOW modelling has identified that tidal flooding in this area is primarily present around Banwell and starts to occur from the 1 in 5 year (20%) flood event. Extents of the flooding increase with rise in return period of each event. During a 1 in 200 year event, the model did not indicate flooding at Winscombe, Churchill or Wrington.

Fluvial flood events are largely as a result of surface water run-off predominantly caused when storm drains reach capacity, causing drains and sewers to surcharge. This is a particular issue within the village of Wrington. The steep escarpment slopes within the southern regions of Area 5 also lead to rapid runoff following storm events with surface water flooding inundating roads and properties particularly in the village of Winscombe.

Due to the complexities of the interactions between surface water flows, existing fluvial systems (that are extensively culverted in part) and a system of storm drains and combined sewers, production of a hydraulic model would require an integrated urban drainage approach. This would combine assessment of the underlying terrain through 2D modelling to identify overland flow paths as well as modelling all sewer and drainage piped networks to determine underground flow routes and capacities. Whilst feasible to construct, this type of model is beyond the scope of this Level 2 SFRA and therefore anecdotal information regarding flood risk quantification has been used along with a more generalised approach. This modelled approach could be incorporated within the SWMP recommended to be undertaken at Wrington.

In the most recent recorded flood events in Wrington during the summer of 2007 and January 2008, flooding extended to The Glebe and Garstons Close from the Rye Brook as well as to Rickyard Road and South Meadows. Floodwaters were of sufficient depth and velocity to not be contained within the highway kerbs.

3.3.6 Flood Zone 3a & 3b

Both Fluvial (1 in 100 year event) and Tidal (1 in 200 year event) flood extents have been mapped in terms of Flood Zone 3a (High Probability) and Flood Zone 3b (Functional Floodplain). This was carried out for the whole of the NSC area and delivered as part of the North Somerset Council Level 1 Strategic Flood Risk Assessment; *Royal Haskoning 2009*.

3.4 Flood Depth

For this section, flooding has been assessed for the 'without defences' scenario for all five areas. The effect of raised defences (present in Areas 1, 3 and 4 only) can be seen in Section 4.3 which includes figures of defended areas as a result of raised defences and descriptions as to the effect of defences on flood depth within these areas. Using the maximum water elevations extracted from the hydraulic models for each return period, we have interpolated the values to produce maximum depths of flooding across each study area.

3.4.1 Area 1: coastal strip from south of Clevedon to Ham Green

Flooding is recorded from the 1 in 5 year return period to the 1 in 200 year return period south of Clevedon. Using TUFLOW, the model indicated that flood depths in this region show a gradual rise in water levels with respect to return period.

Flood depths range from 1.6m (1 in 5 year) to 2.2m (1 in 200 year). The areas affected by flooding do not vary significantly between return periods, after the onset of flooding occurs.

South east of the Royal Portbury Dock flooding is indicated from the lowest modelled event (1 in 5 year) up to and including the highest modelled event (1 in 200 year). The maximum flood depths identified in this region using TIDALB2 have shown an increase in depth with respect to increasing return period.

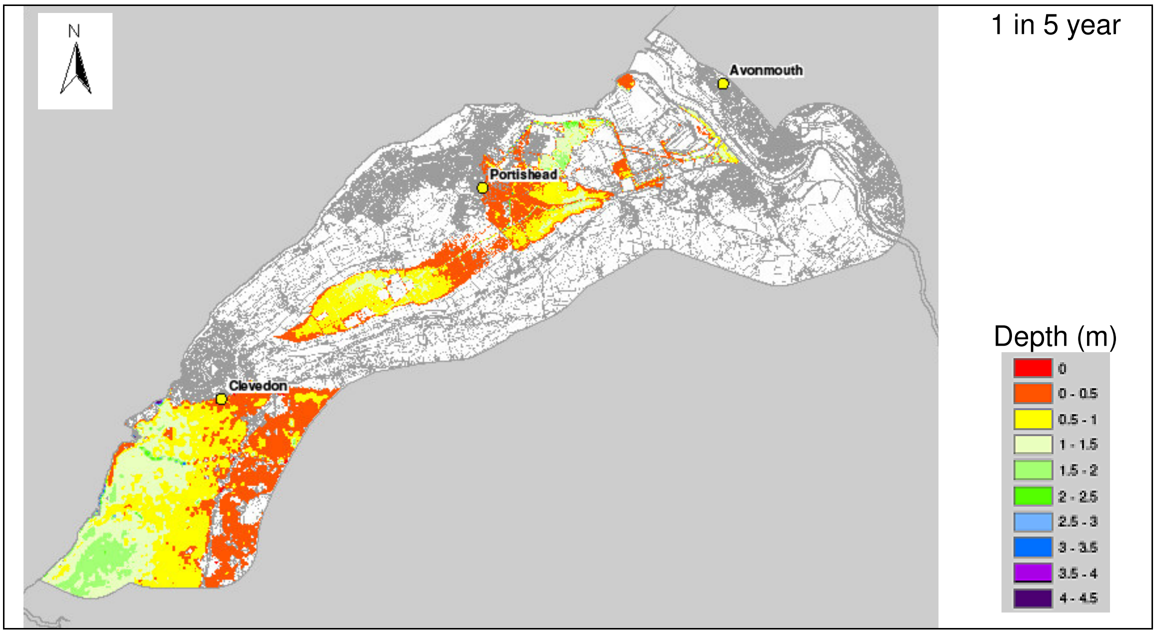
Significant levels of flooding were recorded at the 1 in 5 year event south east of Royal Portbury Dock, with a depth of 3.2m, gradually reaching a depth of 3.7m for the 1 in 200 year event.

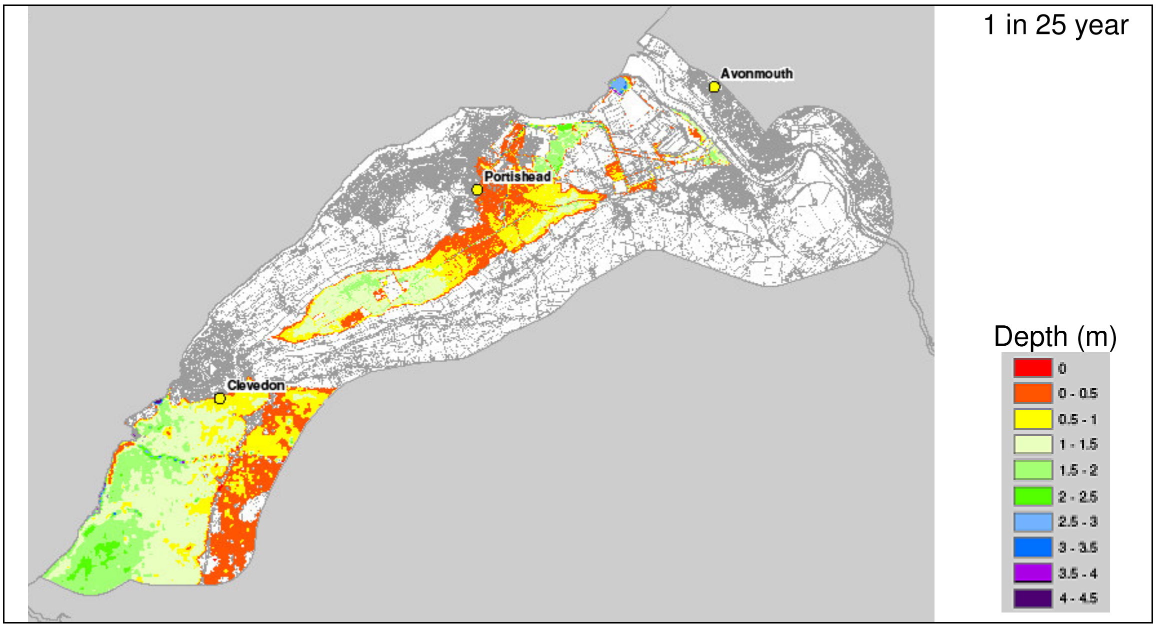
At Portbury Wharf, a large area of tidal flooding is recorded from the 1 in 5 year event, gradually increasing up to and including the 1 in 200 year event. The lowest modelled event recorded maximum water depths of 2.8m on the coastline and 1.8m just south of Portbury Wharf, whereas the highest modelled event produced a depth of 3.1m and 2.25m respectively.

At Clapton in Gordano flooding is recorded from the 1 in 10 year event up to and including the highest modelled event (1 in 200 year). The maximum flood depths recorded in this region using TUFLOW have shown an increase in depth with respect to the ascending return period. Maximum flood depths in Clapton in Gordano range from 0.8m for the 1 in 10 year event, the area of flooding rises incrementally up to 1.1m for the 1 in 200 year event. The 1 in 200 year event at Walton in Gordano recorded a water depth of 0.6m. Depths of flooding are given in Figure 3.14.

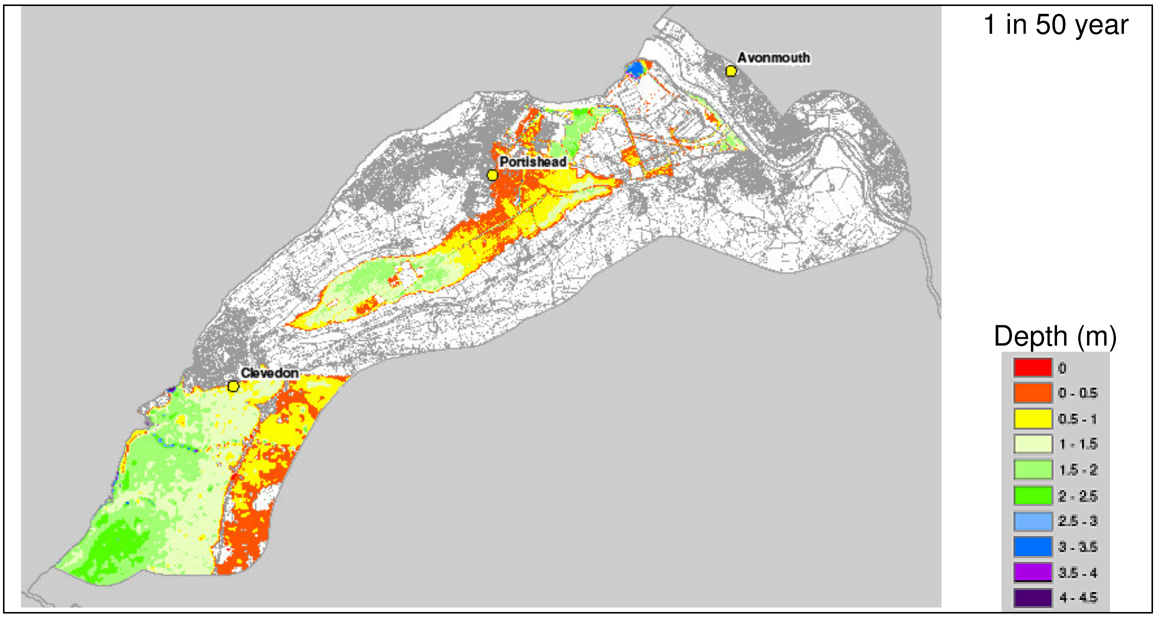
Although a lot of flooding has been recorded in the Portishead/Portbury region, the M5 motorway is shown from the model to be unaffected by floodwater up to and including the 1 in 200 year event.

Figure 3.14: Area 1 Mapped flood depths (without defences)

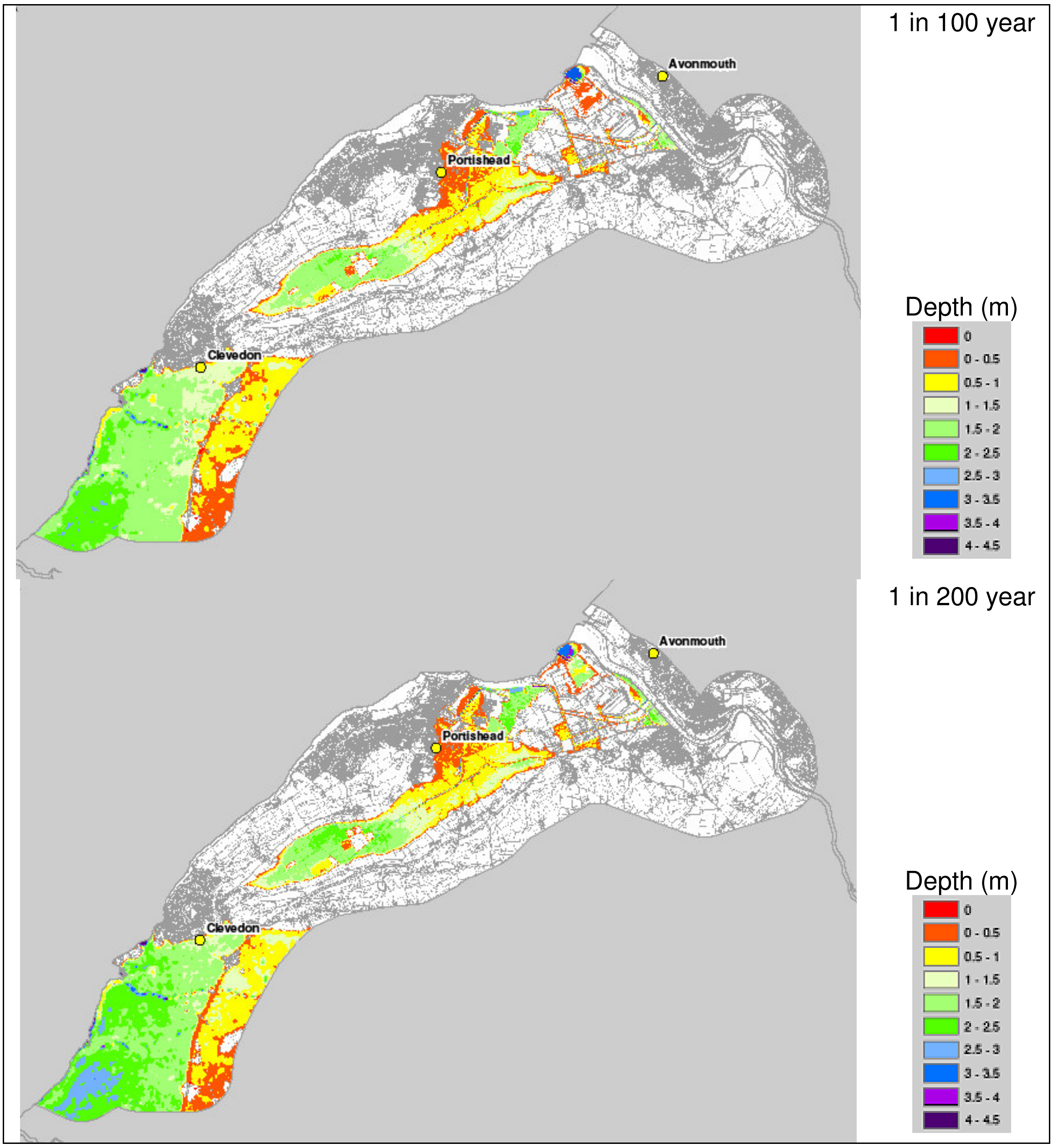




1 in 25 year
Avonmouth
Portishead
Clevedon
Depth (m)
0
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.5



1 in 50 year
Avonmouth
Portishead
Clevedon
Depth (m)
0
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.5



3.4.2 Area 2: urban extension area south-west of Bristol

Between the QMED (50% AEP) event and the 1 in 100 year (1% QMED) event for the region between the Longmoor and Colliters Brooks, water rarely reaches a depth greater than 0.5m. For the 1 in 1000 year (0.1% AEP) event in this area flood depths only increase to 0.7m.

The largest flood depths were recorded to the east of Colliters Brook where depths increase with each increase in return period. For the QMED (50% AEP) event there is a maximum depth of 0.7m increasing to 1.3m by the 1in 10 year (10% AEP) event, and to 1.5m for both the 1 in 100 (1% AEP) and 1 in 1000 year (0.1% AEP) events. Along the left bank of Colliters Brook flood depths are consistently less than 1m for all return periods. Depths of flooding are given in Figure 3.15.

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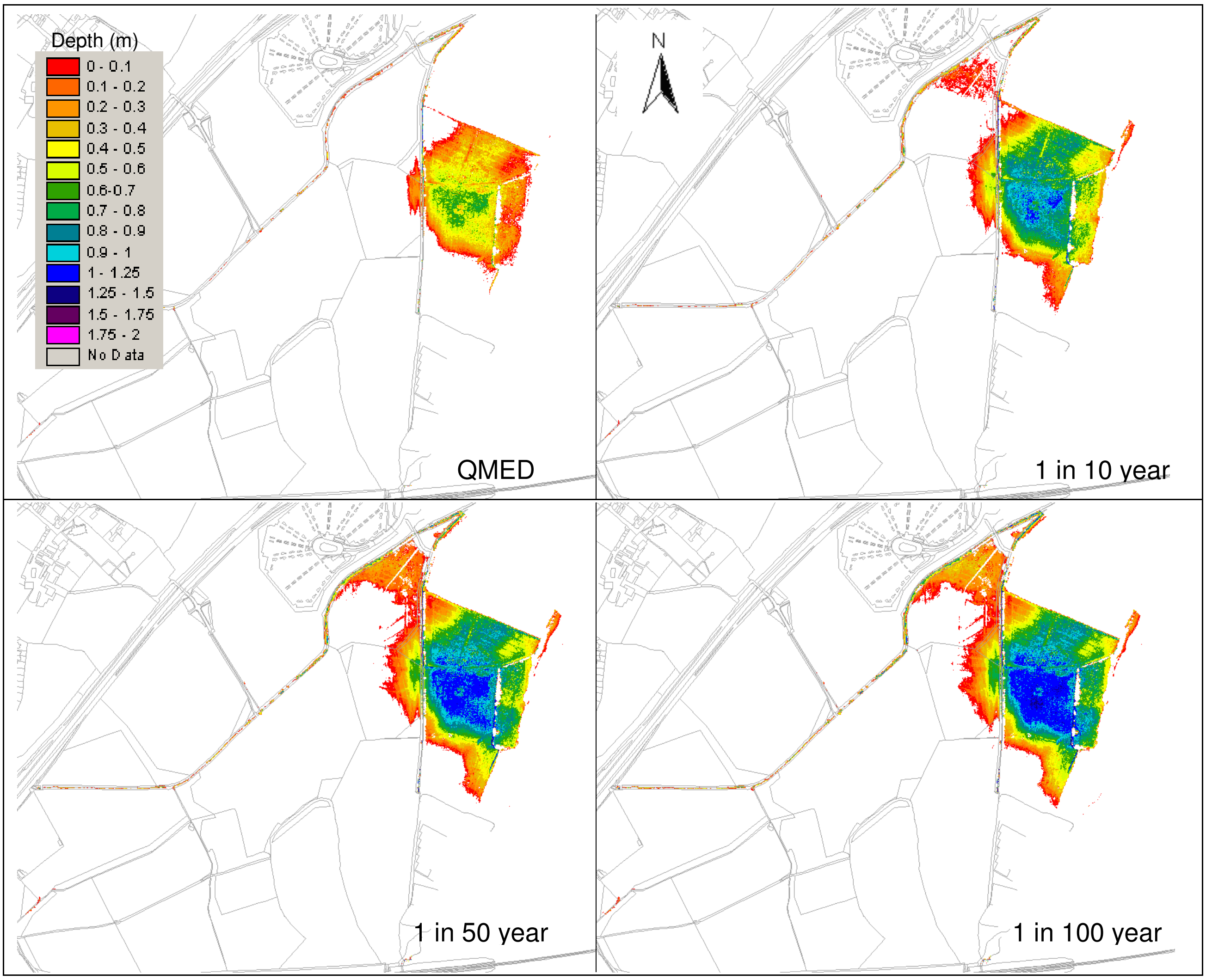
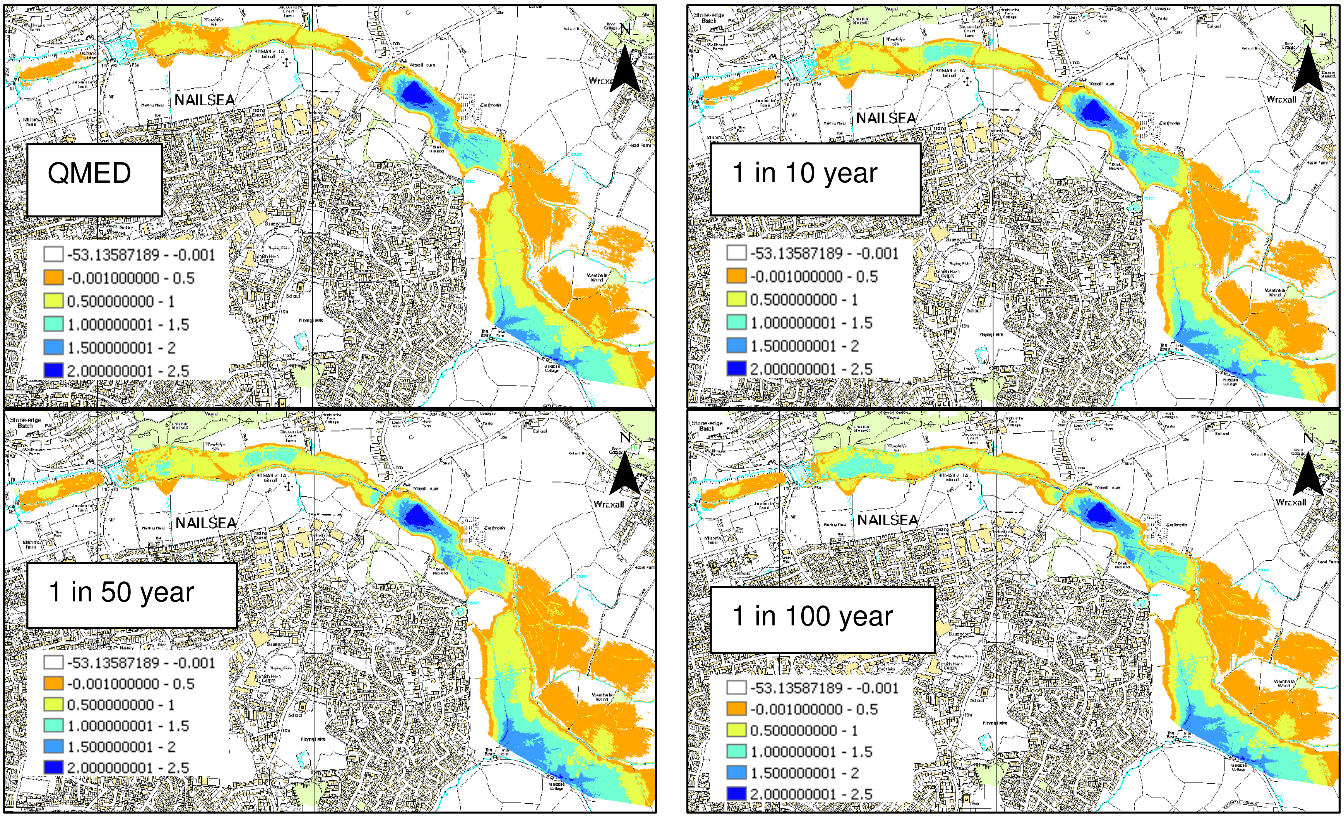
Figure 3.15: Area 2 Mapped flood depths (without defences)



3.4.3 Area 3: land around Nailsea and Backwell

Widespread shallow flooding occurs upstream around Wamballs Farm where during the QMED event (50% AEP) water flows out of bank, flooding neighbouring fields. The depth of flooding does not vary significantly throughout the model with increasing return period. However upstream of Cradle Bridge water depths of up to 2.5m above ground level are recorded for each return period, as shown in dark blue on the maps below. Depths of flooding are given in Figure 3.16.

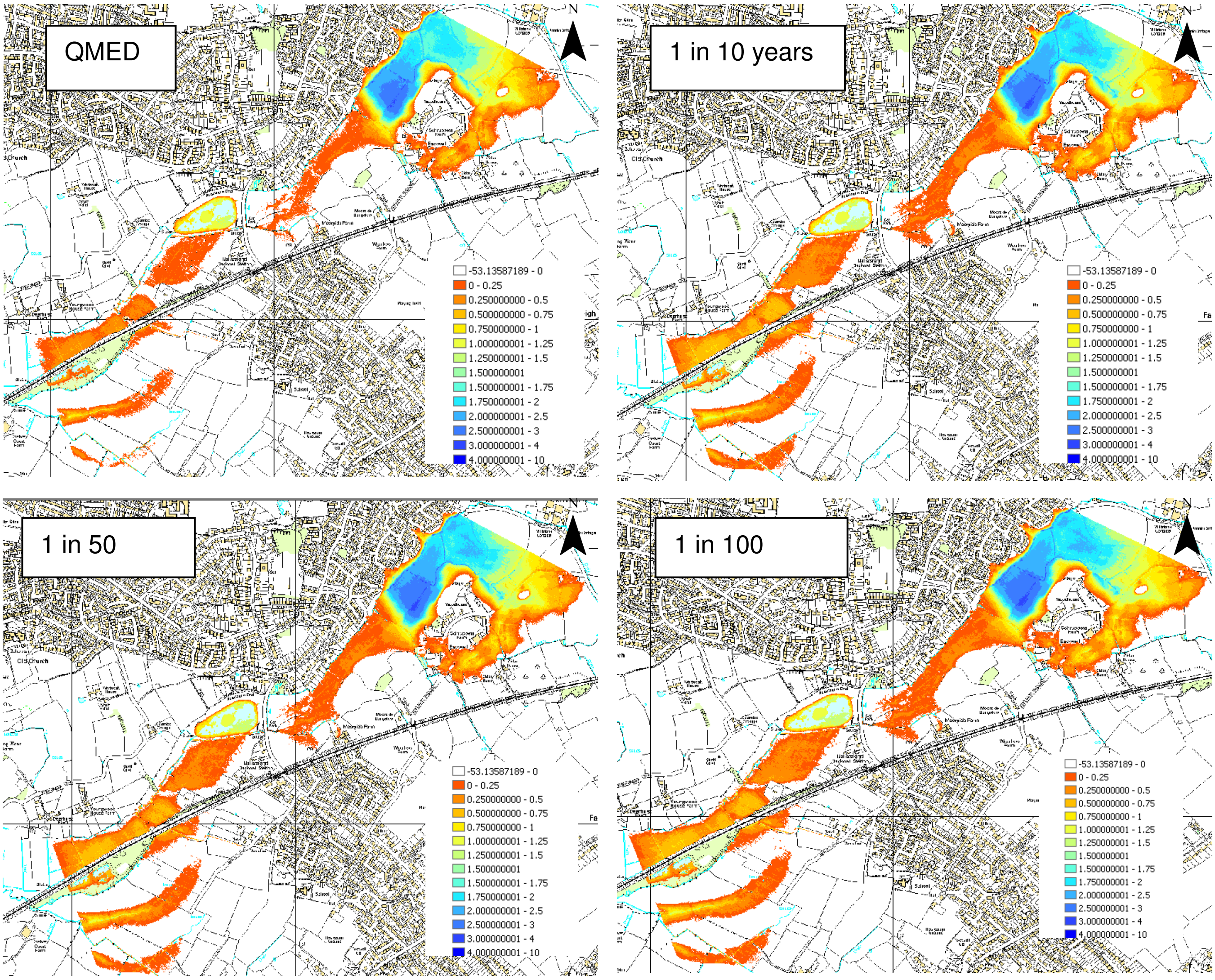
Figure 3.16: Area 3 Mapped flood depths (without defences) northern model



Throughout the eastern model the depth of flooding varies, however for each return period event depths of up to 2.5m above ground level are recorded at the upstream extent of the model around Backwell common.

During a QMED (50% AEP) event a number of properties outside of Backwell Common hamlet are inundated to depths of up to 0.3m. During the 1 in 100 year (1% AEP) event, the extent of flooding increases only slightly at these locations but around Schrubbets Farm, depths reach between 0.8m and 1.0m above ground level. Depths of flooding are given in Figure 3.17.

Figure 3.17: Area 3 Mapped flood depths (without defences) eastern model



3.4.4 Area 4: land around Yatton/Congresbury

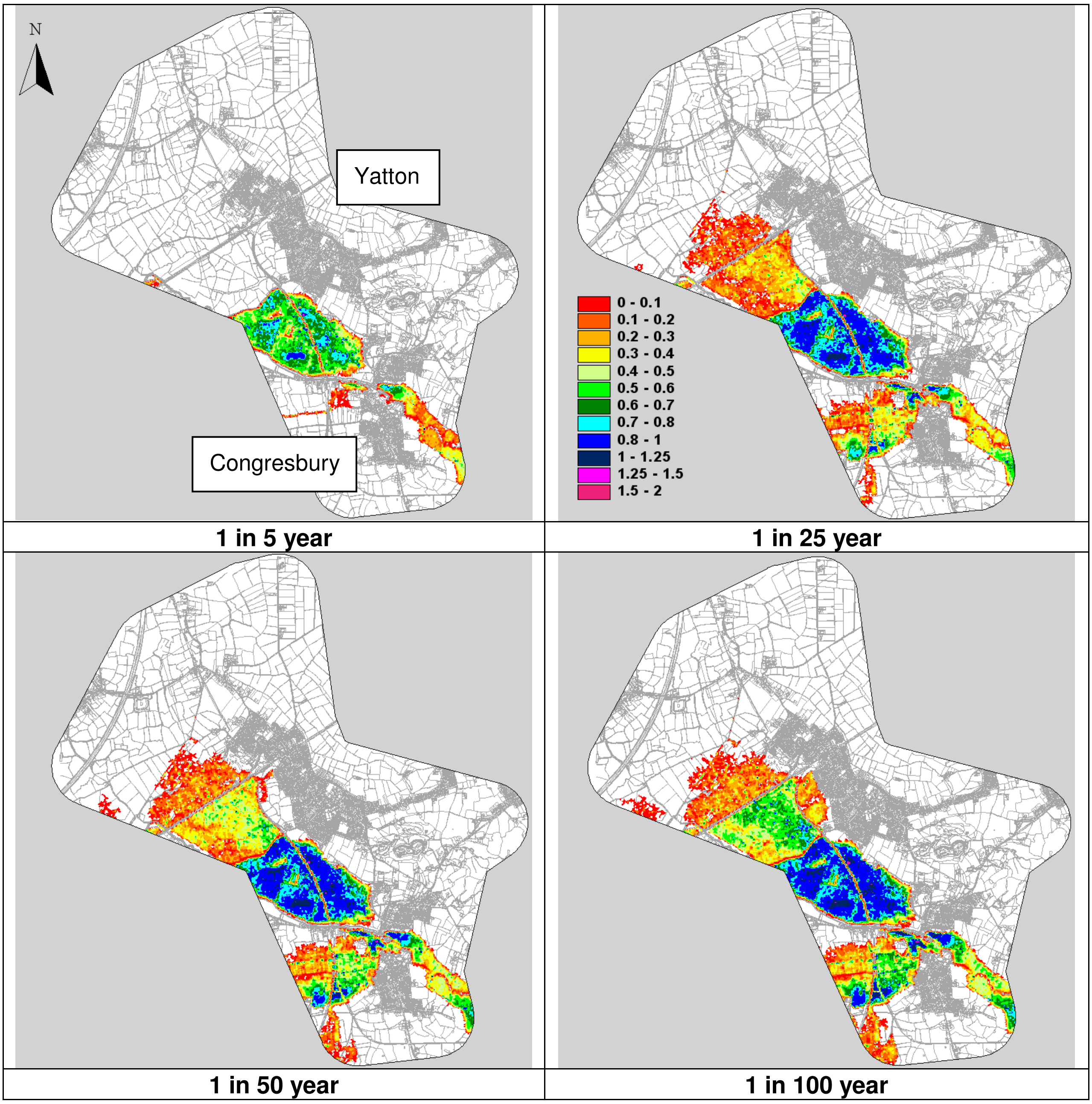
Tidal flood depths in Yatton assessed using the TUFLOW model, varied from 0.3m to 0.7m for the 1 in 10 year event (10% AEP) and between 0.5m and 1.4m for the 1 in 200 year event (0.5% AEP), with flooding primarily to the north and west of Yatton. The largest depth is present to the north of Yatton. At Congresbury recorded depths vary from 0.2m to 1.3m for the 1 in 10 year event (10% AEP) and between 0.3m and 1.6m for the 1 in 200 year event (0.5% AEP). Flooding was recorded primarily to the west of Congresbury.

Fluvial flood depths varied for each return period as shown in Figure 3.18. The greatest depths were recorded to the north-west of Congresbury ranging from a maximum of 1m at the 1 in 5 year event to up to 2m for the 1 in 100 year event.

To the west of Congresbury, flood depths are very low for the 1 in 5 year event at 0.1m or less, ranging from 0.1-1m at the 1 in 25 year (4% AEP) event, the top end of this range increasing to 1.3m by the 1 in 50 year (2% AEP) event with localised depths of 1.5m. Further change is minimal for the 1 in 100 year (1% AEP)event.

South-east of Congresbury, the largest depths lie immediately to the east of the town at 0.8m for the 1 in 5 year (20% AEP) event, increasing up to 1.3m by the 1 in 100 year (1% AEP) event. Further south-east flood depths display an average of 0.3m for the 1 in 5 year (20% AEP) event, increasing to 0.6m by the 1 in 100 year (1% AEP) event. West of Yatton flooding commences at the 1 in 25 year (4% AEP) event for which flood depths are predominantly less than 0.2m and at the most 0.5m. Depths increase with increasing return period to an average of 0.7m by the 1 in 100 year (1% AEP) event.

Figure 3.18: Area 4 Mapped fluvial flood depths (without defences)



3.4.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

Following assessment of the TUFLOW model, tidal flood depths in Banwell varied from 0.3m to 1.1m for the 1 in 10 year event (10% AEP) and between 0.4m and 1.3m for the 1 in 200 year event (0.5% AEP).

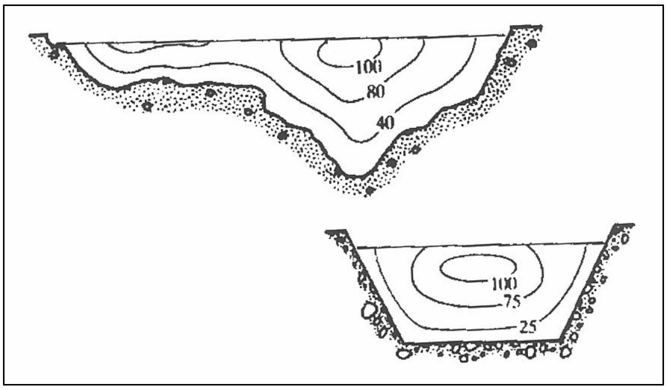
Within Wrington, flood depths of up to 0.9 to 1.2m as a result of highway flooding have been historically recorded with water ponding to over 1.2m in some gardens at Rickyard Road. During the flooding experienced during summer 2007, properties experienced internal flooding for two hours before waters receded. It is therefore reasonable to deduce that flooding was at least at a depth of 0.2m for part of this event.

3.5 Flood Velocity

Where 2D models have been used (Area 1 and Area 4) the velocities can be directly extracted from the model outputs. For the 1D model locations (Area 2, Area 3 and Area 5) we can only extract the maximum velocity for the channel cross sections from this study. Following principles of open channel hydraulics (*CIVE2400: Fluid Mechanics for Open Channel Hydraulics*) the measured velocity in an open channel will always vary across the channel section because of friction along the boundary.

The maximum velocity is usually found just below the surface due to the presence of secondary currents circulating from the boundaries towards the centre and resistance at the air/water interface. Typical channel velocity distributions are given in Figure 3.19. We have therefore assumed the velocity at the banks and of water moving into the floodplain for each of the cross sections is 30% of the maximum velocity. These values can then be interpolated to produce a grid of velocities across the channel extents.

Figure 3.19 Typical velocity distributions



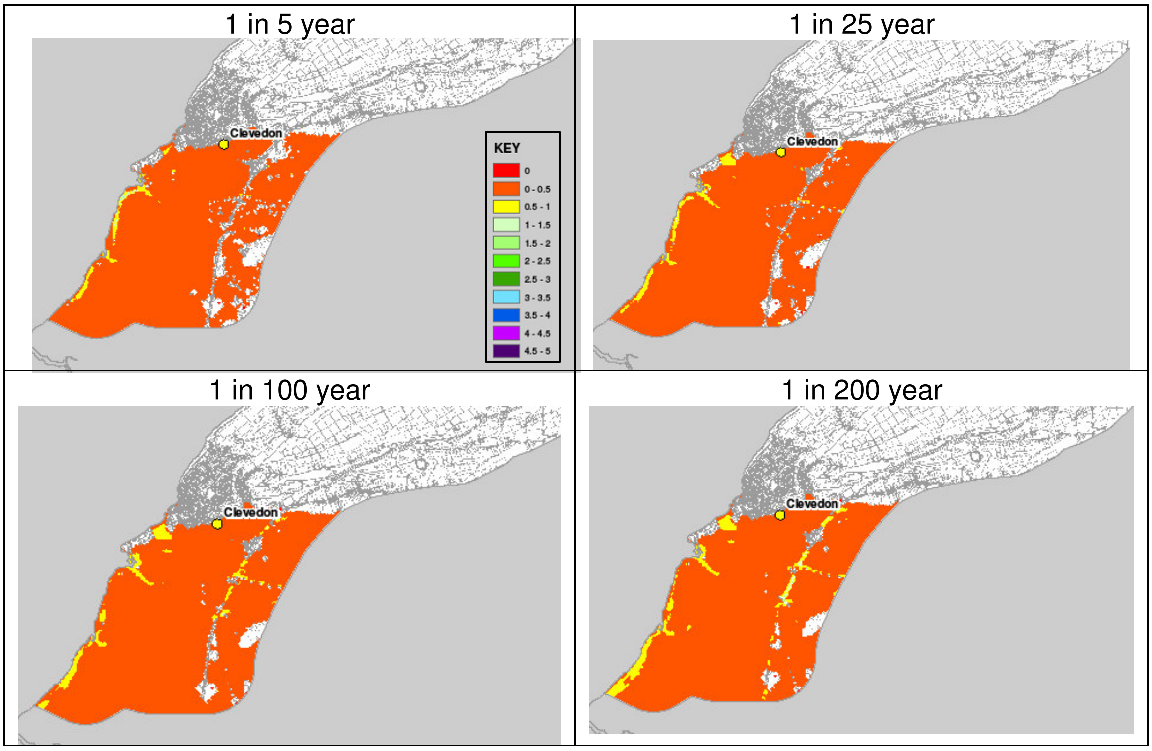
3.5.1 Area 1: coastal strip from south of Clevedon to Ham Green

The velocities of floodwaters south of Clevedon were assessed using the TUFLOW model. The variation in peak velocity is as would be expected, increasing with respect to a larger return period as shown in Table 3.6. Velocities are not generated within the TIDALB2 model and therefore it is not possible to determine velocity. Velocities for the area south of Clevedon (from the TUFLOW model are shown in Figure 3.20).

Table 3.6: Area 1 Maximum flood velocity (from TUFLOW model)

Return Period	Maximum Velocity	Return Period	Maximum Velocity
1 in 5 year	1.03 m/s	1 in 50 year	1.29 m/s
1 in 10 year	1.09 m/s	1 in 100 year	1.47 m/s
1 in 25 year	1.15 m/s	1 in 200 year	1.70 m/s

Figure 3.20: Area 1 Mapped flood velocities (without defences) m/s



3.5.2 Area 2: urban extension area south-west of Bristol

The very small watercourse channels modelled from the Ashton, Longmoor and Colliters Brook show very little variance in velocity across the return periods assessed. Out of bank flows are mainly limited to the downstream areas of the model adjacent to the Longmoor and Colliters Brook. Out of bank velocities are not expected to be significant due to the surrounding topography and the relatively small channel dimensions and therefore have not been mapped. The in-channel velocities for the Colliters Brook and Longmoor Brook at the point where flooding first occurs are given in Table 3.7 below. For out of bank flow we estimate that flows would be approximately 0.25m/s as they left the channel.

Table 3.7: Area 2 in-channel velocity at time out of bank flow commences

Return Period	Maximum Velocity (m/s)	
	Colliters Brook	Longmoor Brook
1 in 10 year	0.82	0.89
1 in 50 year	0.84	0.90
1 in 100 year	0.85	0.91

3.5.3 Area 3: land around Nailsea and Backwell

Using the results from the northern and eastern 1D HECRAS models the channel velocities were extracted and assessed at each cross section for each return period. During the assessment three locations were identified as areas which experience out of bank flow and that have high velocities. These areas were investigated further.

At Cradle Bridge (northern model: cross section 2505) out of bank flow occurs and depths of flooding exceed 2.0m in a QMED event. At Backwell Common (eastern model: cross section 2349) deep flooding occurs in close proximity to a number of residential properties. At Nailsea and Backwell Station (eastern model: cross section 1179) overbank flows are experienced on the left bank and the model indicates increased velocities at this location. The approximate locations of these cross sections can be seen on Figure 3.12.

Table 3.8: Area 3 Maximum Velocities at selected cross sections

		Return Period			
		QMED	10 year	50 year	100 year
Model	Cross section	Max Velocity (m/s)	Max Velocity (m/s)	Max Velocity (m/s)	Max Velocity (m/s)
North	2505	1.41	1.65	1.85	3.32
East	2349	1.09	1.2	1.37	1.48
East	1179	1.35	1.42	1.7	1.78

Due to the limitations of 1D modelling the figures in Table 3.8 are 'in bank' velocities. It is not possible to calculate velocities for overland flows as storage areas and lateral spills are not present in the 1D model. However if we assume that at the time at which over bank flows occurs velocities are 30% of maximum velocities in the channel we estimate velocities of approximately 1m/s in the northern model and 0.5m/s in the eastern model for the 1 in 100 year (1% AEP) event.

3.5.4 Area 4: land around Yatton/Congresbury

Peak velocities for the 1 in 200 year (0.5% AEP) event are 0.3m/s to the west of Congresbury. For the majority of the area velocities remain below 0.1m/s.

To the north-west of Congresbury and west of Yatton out of bank velocities average at between 0-0.03m/s for all return periods. Within this region an area is identified as having elevated flow velocities of 0.1-0.5m/s for the 1 in 25 year (4% AEP) event. For the 1 in 50 (2% AEP) and 1 in 100 year (1%AEP) events the average increases to between 0.5 and 0.8m/s however maximum velocities decrease to less than 1m/s.

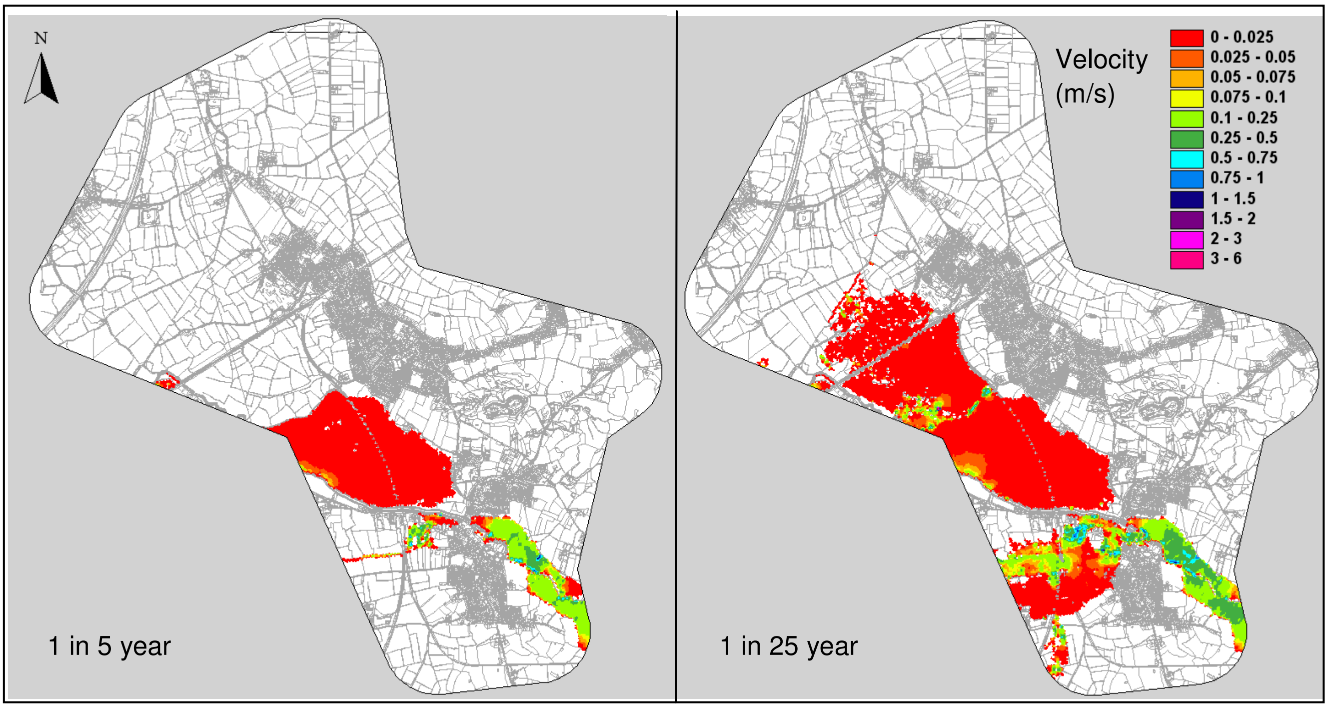
West of Congresbury flooding is scarce at the 1 in 5 year (20% AEP) event; where it occurs flow velocities average between 0.1 and 0.5m/s. Flood extents in this region significantly increase by the 1 in 25 year (4% AEP) event with velocities of 0-0.3m/s. Closer to the town average velocities range from 0.5 to 0.8m/s, maximum 1.9m/s. No increases in velocity are recorded for the 1 in 50 year (2% AEP) event. For the 1 in 100 year (1% AEP) event, velocities increase to between 0.8-1.4m/s the latter expressing the maximum for this return period.

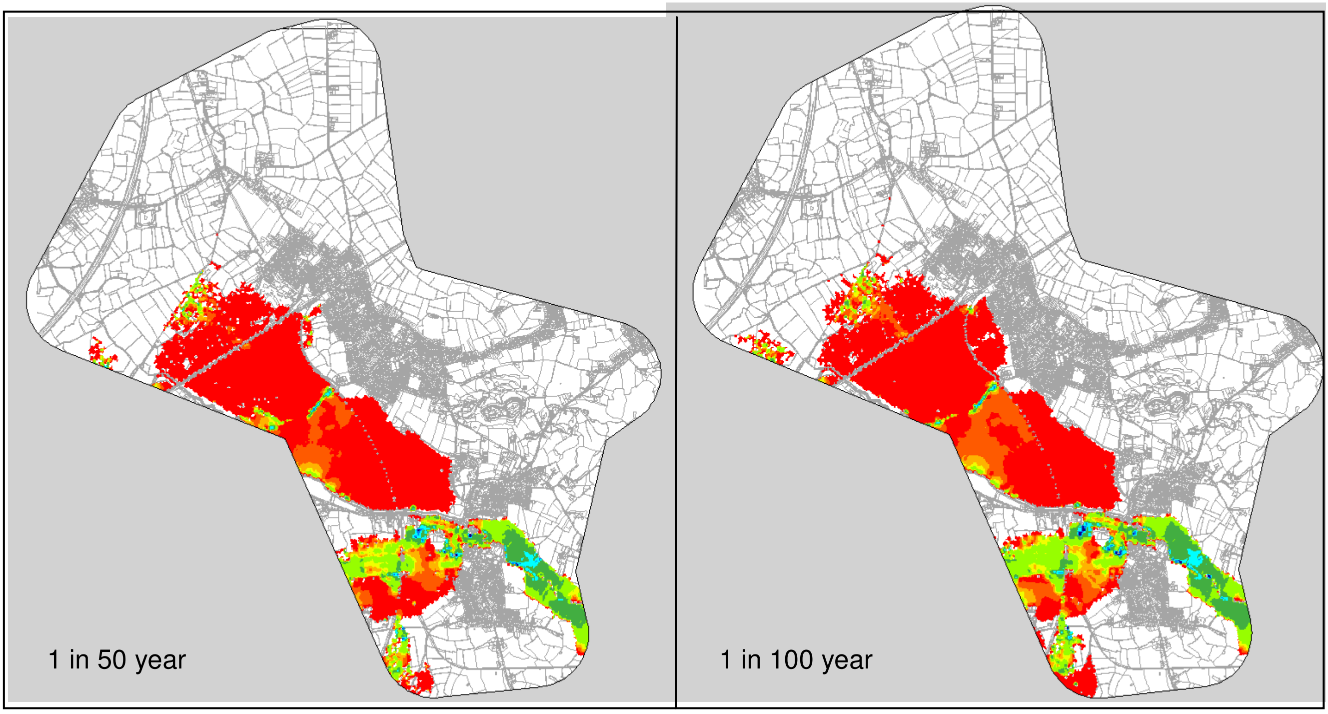
To the south-east of Congresbury average velocities vary between 0.1 and 0.3m/s for the 1 in 5 year (20% AEP) event, extending to 0.5m/s for the 1 in 25 (4% AEP), 1 in 50 (2% AEP) and 1 in 100 year (1% AEP) events. The maximum velocity in the south-east occurs at the 1 in 5 year (20% AEP) event with a value of 1.1m/s. Maximum velocities are given in Table 3.9.

Table 3.9: Area 4 Maximum flood velocity (from TUFLOW model)

Return Period	Maximum Velocity (m/s)
1 in 5 year	1.1
1 in 25 year	1.2
1 in 50 year	1.2
1 in 100 year	1.4

Figure 3.21: Area 4 Mapped flood velocities (without defences)





3.5.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

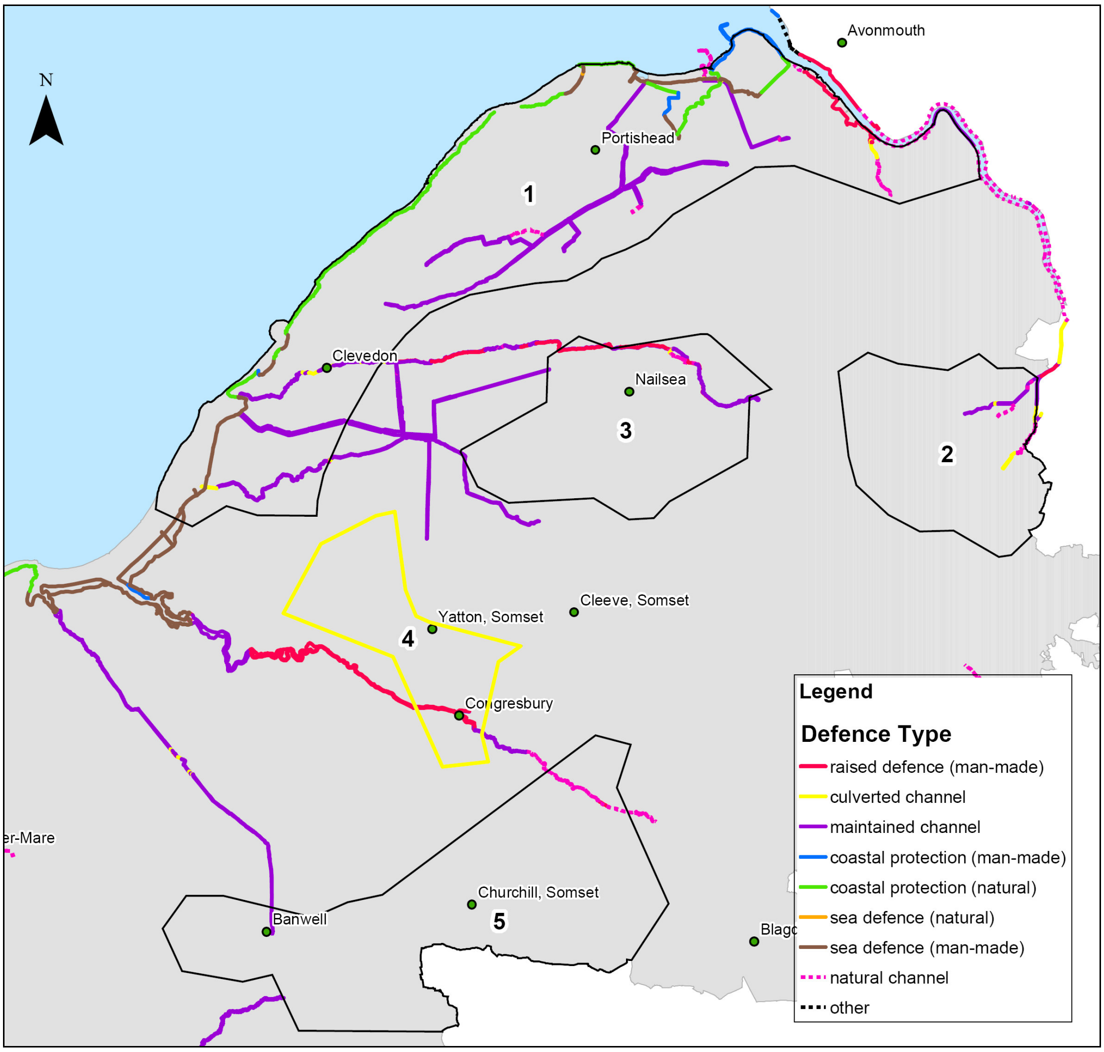
The variation in velocity for tidal flooding is limited as Area 5 is at the most inland extent of tidal flooding. Peak velocities for the 1 in 200 year event are 0.1m/s to the north of Banwell. For the majority of the rest of the area velocities remain below 0.01m/s. As there is no model available for this area, fluvial velocities are not obtainable. In Wrington quantitative assessments of flood water velocity have not been made though incidents of ‘very fast flowing’ floodwaters have been recorded.

4 VERIFICATION OF DEFENCES AND DEFENDED AREAS

4.1 Overview of defences and maintained channel

Defences are present within Areas 1, 3 and 4 with Area 1 defences affording protection against tidal flooding and Area 3 and 4 defences against fluvial flooding. Brief descriptions of the defences are given in the North Somerset Level 1 SFRA (Royal Haskoning 2008). Figure 4.1 provides an overview of the channel classification (as per NFCDD) for the study area. Over 56% of the 'defences' in the study area are classified as maintained channel and there are approximately 2.5km of raised defences within Area 1, 3km within Area 3 and 3.3km within Area 4. Coastal protection is predominantly natural though there are extensive areas of man made sea defences to the south of Clevedon and at Portishead.

Figure 4.1: Channel classification (from NFCDD)



Maintenance of watercourses located within the five Level 2 areas in North Somerset is carried out at a variety of intervals and relates predominantly to the cutting of vegetation (weed cutting). Maintenance regimes undertaken by the Environment Agency for each area are summarised below.

4.1.1 Area 1: coastal strip from south of Clevedon to Ham Green

This Area includes watercourses from the Kenn, Portbury Ditch and Avon Bristol Tidal catchments.

- Weed cutting is generally carried out either annually or biannually (for example July and October for Land Yeo River, Weston Drove Rhyne, Blind Yeo River and Walton Brook) with the exception of annual weed cutting maintenance on the River Kenn in September and initial weed cutting in June rather than July on Clapton Drove and Sandy Rhynes.
- Regarding the Portbury Ditch, weed cutting is performed 1-2 times per year in July and October with the following exceptions:
    - A single weed cut is carried out within the SSSI area
    - 20% weed coverage is left at the water's edge of the left hand bank
    - Downstream of A369 Bridge weed cutting is performed 1-2 times per year in August and October.
- For Drove Rhyne, weed cutting is performed annually in July in addition to the spraying of herbicide where access is restricted at the rhyne outfall.
- Sea defences (Marshall's) in the Kenn catchment section of area 1 are subject to flailing annually in September. Maintenance regimes for Portbury Ditch catchment area sea defences are unknown.
- Non-routine maintenance includes gate and fencing repairs to Walton Brook, Portbury Ditch gateway, River Kenn gateways (Areas 1 and 3) and Davis Lane over a total of 46 days.
- Projected maintenance within Area 1 includes activities such as work on the Clevedon Seawall Joints and the Blind Yeo Gabions.

4.1.2 Area 2: urban extension area south-west of Bristol

Maintenance regimes for watercourses in this area (including Colliter's Brook, Longmoor Brook and Ashton Brook in the Avon Bristol Tidal catchment) were not available from the Environment Agency.

4.1.3 Area 3: land around Nailsea and Backwell

This area is located entirely within the Kenn catchment area.

- The River Kenn is a maintained channel on which weed cutting and flailing is performed biannually in June and September.
- The Land Yeo River comprises natural, maintained and culverted channel sections in addition to incorporating the Wraxall Gauging Station. Weed cutting is performed twice per year in July and October. Regarding the Blind Yeo River, weed cutting is carried out 1-2 times per year also in July and October.
- Non-routine maintenance includes gate and fencing repairs to the River Kenn gateways (6 days).

4.1.4 Area 4: land around Yatton/Congresbury

- Flailing is carried out twice per year on the Congresbury Yeo River with weed cutting as required.
- Projected maintenance within area 4 includes work concerning Gooseham Rhyne.

4.1.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

- Weed cutting is carried out 1-2 times per year on the Lox Yeo River, initially in July.
- Weed cutting is performed on the right bank of the Banwell River once per year and on the left bank, 2-3 times per year in June and August or September.
- Additional biannual maintenance performed in the Axe catchment section of the area includes; maintaining pumping stations, structures and water level management and life saving equipment checks. Weekly Flood Alleviation Scheme (FAS) inspections and pre-tide inspections are also completed.

Maintenance regimes for privately maintained channels are unknown.

4.2 Standard of Protection

We have assessed the standards of protection recorded by the EA within NFCDD as well as reviewed later data that has been used to inform the National Flood Risk Assessment process that is currently under review by the North Wessex Environment Agency office. We have supplemented this assessment with crest level survey information (collected in 2007 and available for some of the defences within the areas of study) and analysis of ‘with defences’ scenarios within the hydraulic models discussed in Section 3 where appropriate. Standards of protection have been summarised in Figures 4.3 to 4.6.

4.2.1 Area 1: coastal strip from south of Clevedon to Ham Green

Raised defences are present within the study area.

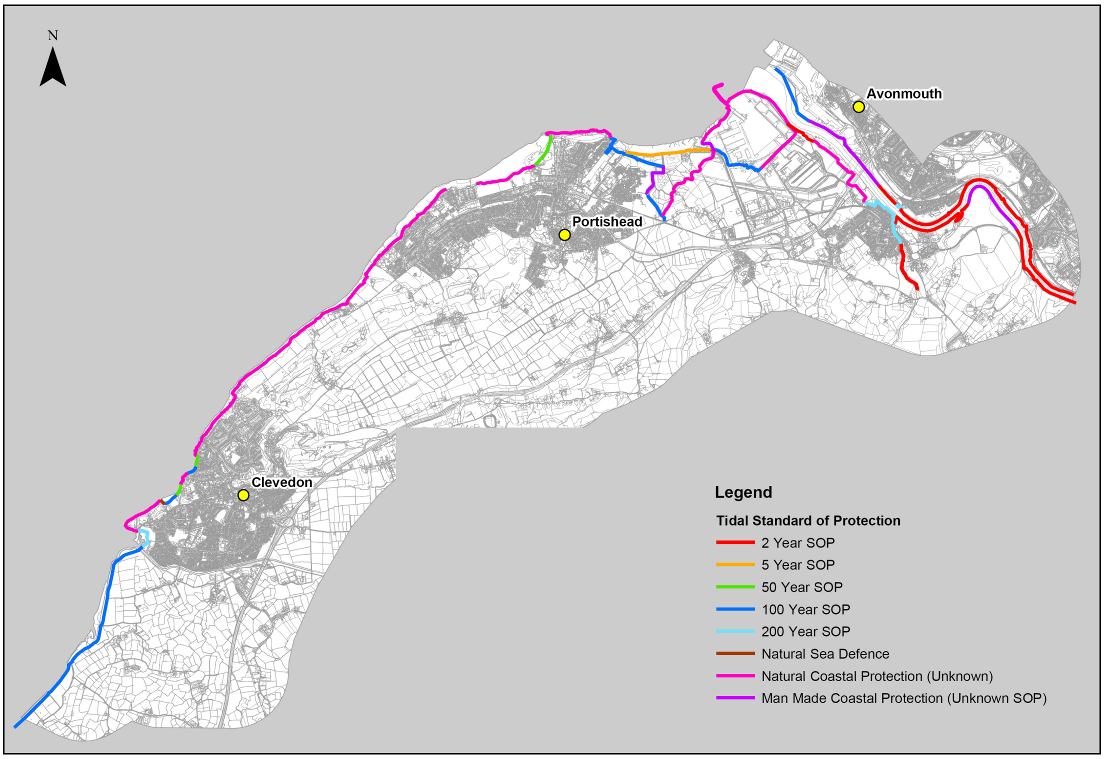
At Clevedon the standard of protection for man-made sea defences varies between 1 in 5 and 1 in 100 year levels. The majority of defences between Huckers Bow and Sugar Loaf Beach provide protection to a 1 in 100 year standard.

Between Portishead and Royal Portbury Docks, the standard of protection also varies between 1 in 5 and 1 in 100 year levels. At Portbury Wharf, the coastal defence standard of protection is equal to a 1 in 5 year standard.

For the area of Royal Portbury Dock, known defence heights were not available from the Environment Agency and thus heights were verified using LiDAR DTM data and the standard of protection determined from the associated variation in extreme water levels used within the hydraulic modelling to assess at what return period defences were overtopped. In places this could be as low as a 1 in 2 year standard of protection as shown in Figure 4.2. This is therefore a key area for possible future improvements.

The modelling has shown that the area east of the A369 at Portishead becomes inundated from the 1 in 50 year return period onwards leading to larger areas of flooding west of Portbury Wharf from the 1 in 100 year return period onwards.

Figure 4.2: Area 1 Standards of Protection

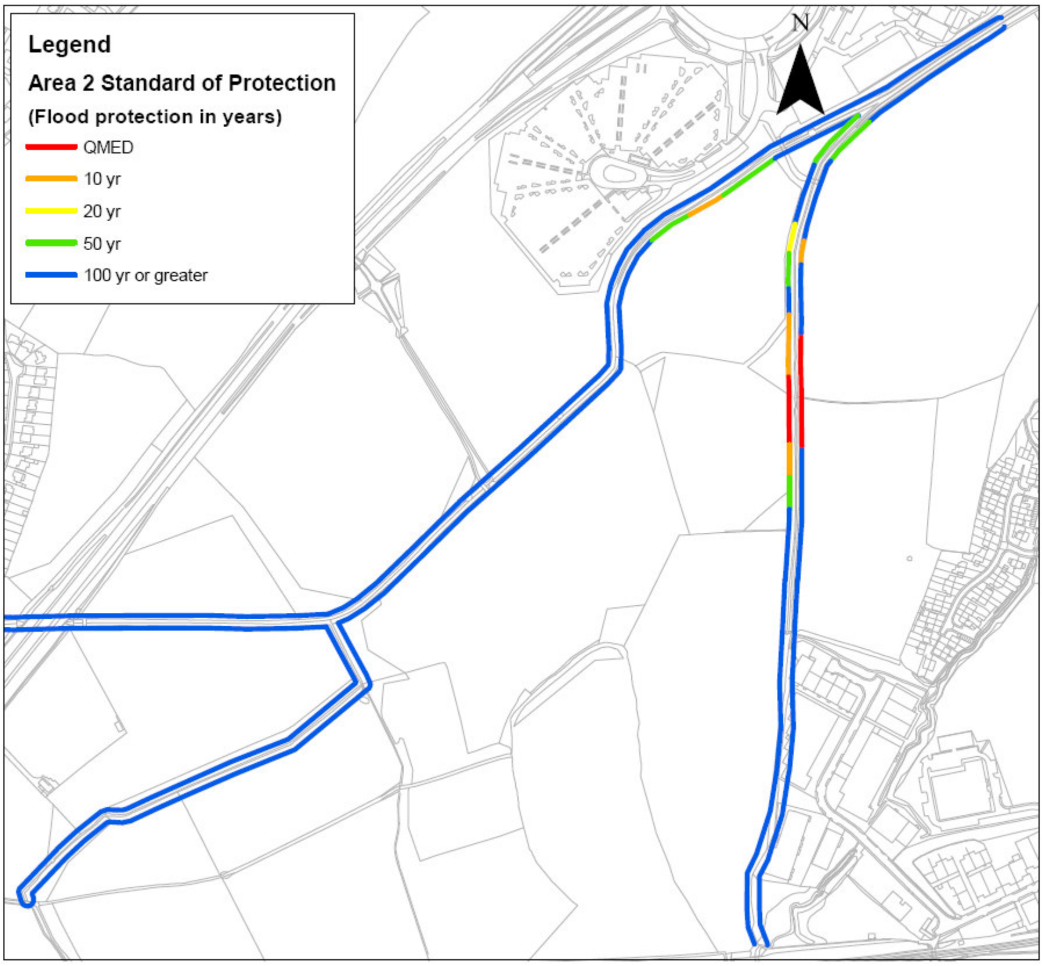


4.2.2 Area 2: urban extension area south-west of Bristol

As raised defences do not exist within the study area the standard of protection is not directly recorded for defences but a standard of protection has been defined for the mainly natural channels used within the model extents. The standards of protection are given in Figure 4.3 based on evaluation of the modelled onset of flooding.

For the Ashton Brook, flow is contained mainly within the channel for all studied return period events. This is also true for the majority of the Longmoor Brook with the exception of the area to the south-east of the Long Ashton Park and Ride site where flows spill from right bank of the channel for return periods greater than and including the 1 in 10 year event. The return period for the on-set of flooding for the section of Colliters Brook (approx. 0.5km) upstream of the confluence with Longmoor Brook is the QMED event. The flood extents for Area 2 are given in Figure 3.11 in Section 3.3.2.

Figure 4.3: Area 2 Standards of Protection



4.2.3 Area 3: land around Nailsea and Backwell

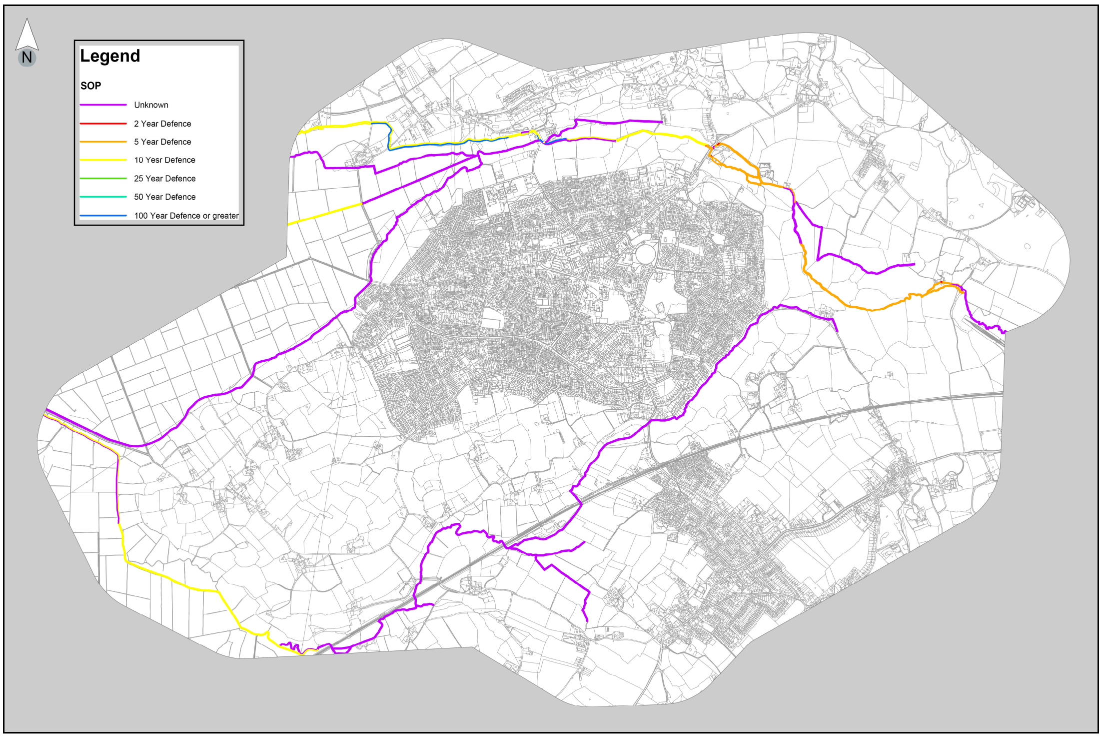
Data from the Environment Agency has been used to assess the standard of protection of the banks within the northern model which are classified as raised defences, with standards of protection ranging from QMED to 1 in 100 years. At the upstream extent, there is a 1 in 5 year standard of protection for 1.5km, followed by no protection for the next 0.3km, after which a 1 in 5 year standard of protection is given to the next 800m which finishes at Cradle Bridge. Around the bridge there are small sections at a 1 in 2 year standard. The next section is predominantly a 1 in 10 year standard of protection, however for 150m the right bank is raised to a 1 in 100 year standard. The left bank shows no protection. A 1 in 10 year standard is given to both banks before the left bank is increased to a 1 in 100 year standard for the last 100m of the model extents.

Figure 4.1 shows the locations of defence types within Area 3 and the standards of protection are given in Figure 4.4. The raised defences includes natural defence (natural and earth banks), flood walls (gabion and masonry), embankments, abutments and stone pitching. Approximately three quarters of these defences are maintained by the Environment Agency and the remainder by private landowners .

Raised defences do not exist within the eastern model. The standard of protection has been defined using the natural channel. The standards of protection are given in Figure 4.4 based on evaluation of the onset of flooding for each return period assessed.

An assessment has been made to compare the EA standard of protection data against the modelling that has been undertaken. The model was built to include the level of the defence at the location of each cross section, which were placed at regular intervals along the watercourse. For this reason some stretches of the model do not show flooding out of bank but water may spill at sections of the bank where levels may be lower (and in between the cross sections recorded). The extent of flooding has been displayed by taking the water level from the HEC-RAS model and flooding the Lidar data. This data can be analysed to assess the standard of protection offered by the defences as the defence (shown as higher topographic levels) will not be shown as flooded area and therefore still be visible.

Figure 4.4: Area 3 Standards of Protection (from EA data)



4.2.4 Area 4: land around Yatton/Congresbury

Raised defences are present along both banks of the Congresbury Yeo within the study area and are shown on Figure 4.1. Standards of protection are given in Figure 4.5. The flood extents, with defences for the QMED (50% AEP), 1 in 10 year (10% AEP), 1 in 50 year (2% AEP) and 1 in 100 year (1% AEP) probability flood events derived from this model have been mapped using the LiDAR DTM for the area surrounding Congresbury and to the south of Yatton. The model extends further to the west: only key results directly relating to Area 4 are shown.

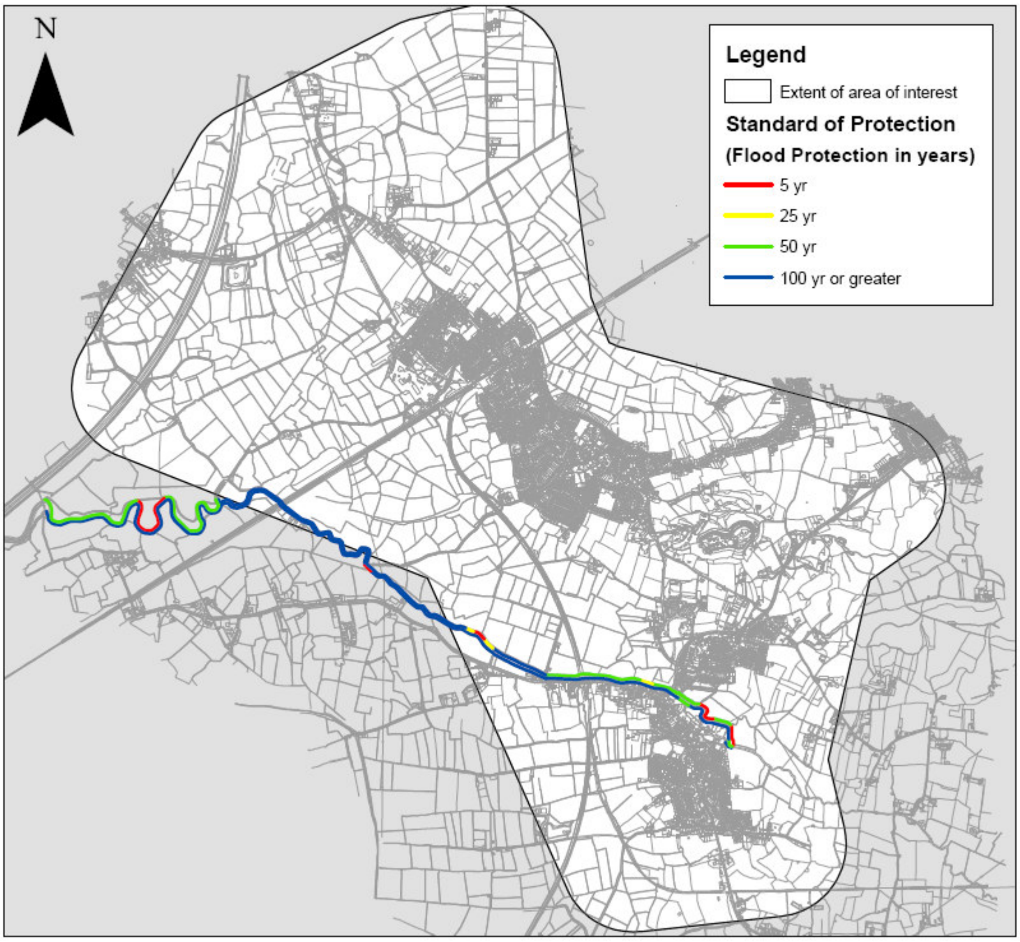
The majority of defences along the Congresbury Yeo take the form of raised embankments and generally provide a 1 in 100 year standard of protection according to both NFCDD and the model output. However there are sections where this is reduced to 1 in 5 year levels.

With the exception of a section of the defences upstream of Congresbury Bridge (to the east of the area) at the 1 in 50 year level, and a section at the 1 in 5 year level at Pilhay Bridge, the left bank of the Congresbury Yeo within the model area offers a 1 in 100 year standard of protection.

The right bank displays a more varied level of defence. Upstream of Congresbury Bridge defence levels alternate between a 1 in 5 and 1 in 50 year standard of protection. Immediately downstream of the bridge the standard of protection is 1 in 50 year interspersed with a 90m section at 1 in 25 year. The standard of protection is then maintained at the 1 in 100 year level with minor sections of 1 in 5 and 1 in 25 year levels until East Hewish where the standard of protection varies between 1 in 25 and 1 in 50 year levels.

The standards of protection are given in Figure 4.5 based on evaluation of the onset of flooding for each return period assessed.

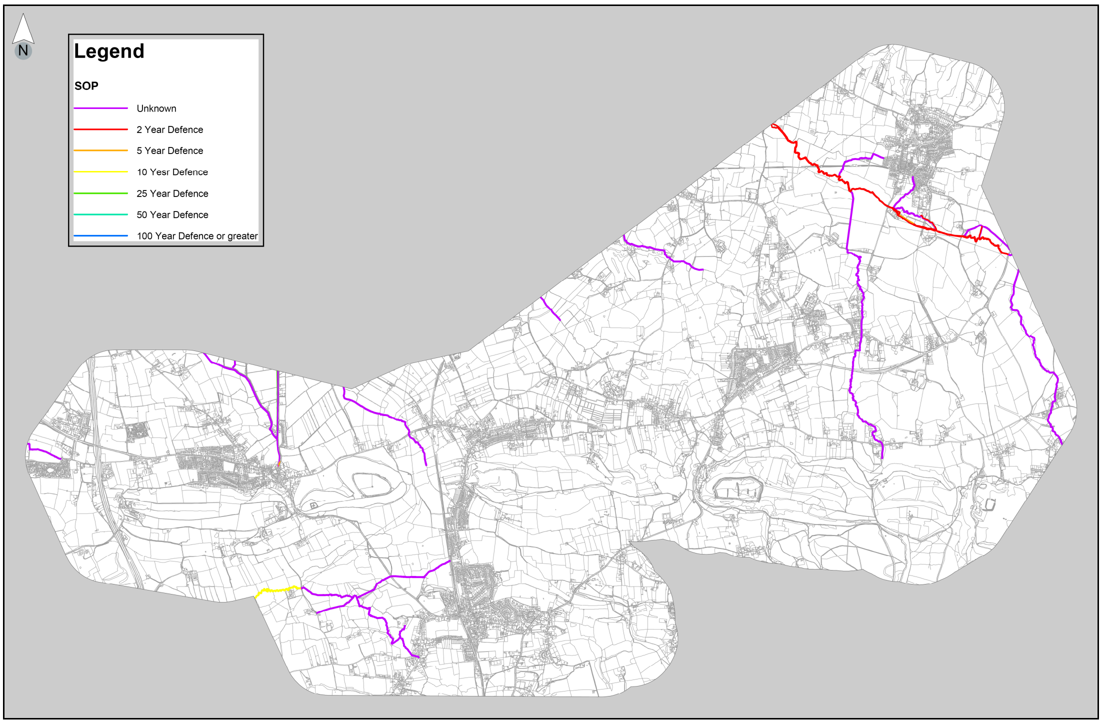
Figure 4.5: Area 4 Standards of Protection



4.2.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

As this Area has not been modelled, standards of protection have not been further assessed through review of the return period of the onset of flooding. Figure 4.6 however gives the standards of protection as recorded by the Environment Agency for the study area. There are no raised defences within the area.

Figure 4.6: Area 5 Standards of Protection



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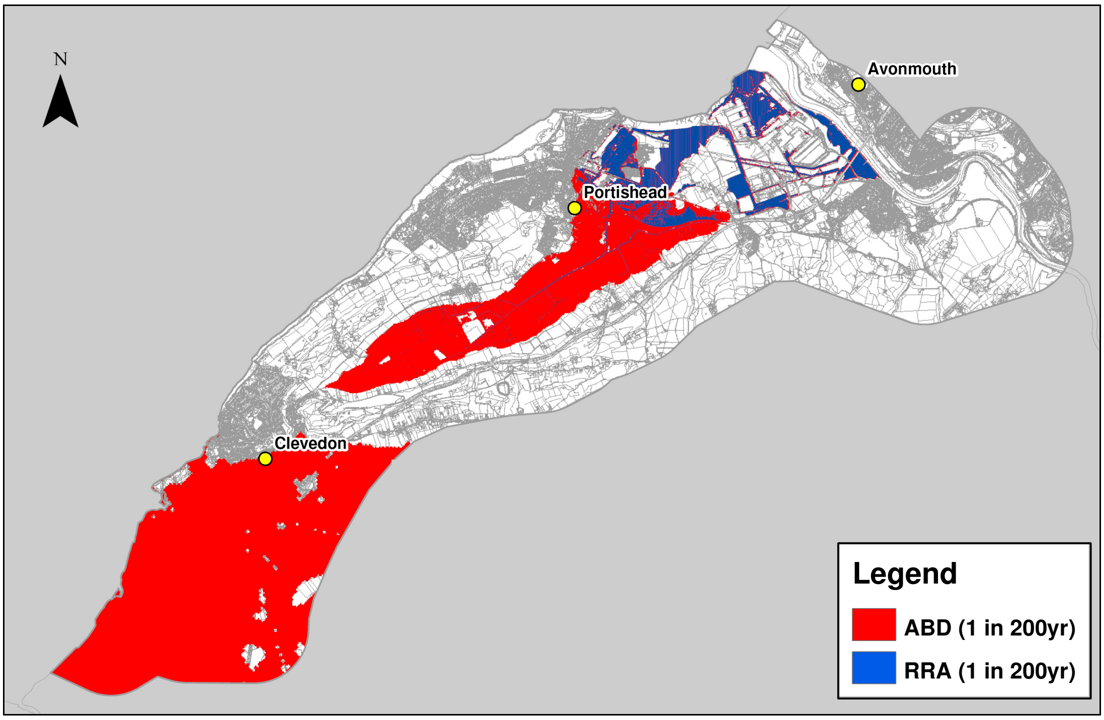
4.3 Defended Areas

4.3.1 Area 1: coastal strip from south of Clevedon to Ham Green

Defences are present along significant sections of the coastline in this area allowing many areas to benefit from defences. These include the coastal region south of Clevedon extending landward to Area 4 and 5 and land south of Portishead between Upper Caswell Farm to Clapton in Gordano and Nortons Wood. The Areas Benefitting from Defences (ABD) and the extent of protection offered by the defences can clearly be seen on Figure 4.7 as the areas where flooding at the 1 in 200 year (0.5% AEP) return period no longer occurs, shown as the red extents and the Residual Risk Areas (RRA) of the FZ3 Extent shown in blue.

Significant differences in depths between the undefended and defended scenarios are localised to the area to the south east of Portbury Wharf. At the 1 in 5 year (20% AEP) event, depths at this location are 0.2m lower for the defended situation and 0.36m lower for the defended situation at the 1 in 200 year (0.5% AEP) event. As the standard of protection at Portbury Wharf is between a 1 in 2 and 1 in 5 year standard the general differences in depths between the defended and undefended scenarios would be expected to be marginal across the majority of the flood risk area.

Figure 4.7: Area 1 Defended Areas



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4.3.2 Area 2: urban extension area south-west of Bristol

As raised defences do not exist within the study area an assessment of the areas benefiting from defences has not been carried out.

4.3.3 Area 3: Land around Nailsea and Backwell

From an initial assessment of the modelling undertaken at Nailsea there are limited areas benefiting from defences apart from the areas adjacent to Jacklands Bridge for the QMED (50% AEP) event. The extent of the defended area decreases with increasing return period and above the 1 in 10 year (10% AEP) event there is no defended area as the standard of protection (1 in 10 year) has been compromised.

Due to the broadscale modelling approach and the use of limited cross sections without topographic survey the variable defence height between cross sections has not been represented within the model. Therefore it is not possible to predict in any more detail where defended areas occur. A more detailed hydraulic modelling study with topographic survey would need to be undertaken to provide this information. Raised defences do not exist within the eastern model, therefore an assessment of the areas benefiting from defences has not been carried out.

With regard to flood depths for the 'with defences' situation there is very little difference between the depths identified from the modelling for the undefended and defended situations. This is because the standard of protection is relatively low along most of the sections of the channel where raised defences occur and overtopping starts to occur at the QMED event (50% AEP).

4.3.4 Area 4: land around Yatton/Congresbury

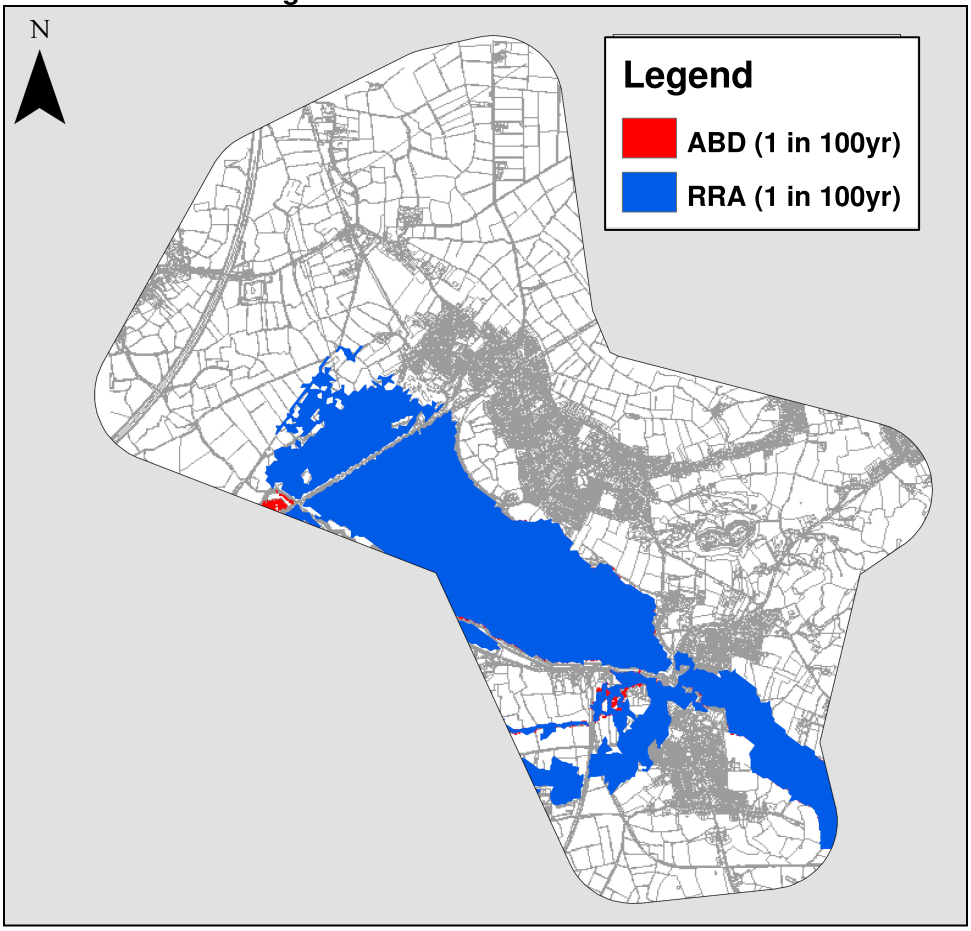
The model indicates that flood extents within the area of interest to the south-east of Congresbury have not been greatly influenced by the presence of defences since extents remain similar for both ‘with’ and ‘without’ defence scenarios. The greatest impact is apparent to the west of Congresbury where onset of flooding is reduced from the 1 in 5 year event (without defences) to the 1 in 50 year (2% AED) event (with defences). In addition significantly less flooding occurs for the 1 in 100 year (1% AED) event. North-west of Congresbury and west of Yatton extents for the 1 in 5 year (20% AED) event are reduced overall but extend further north. For the 1 in 25 (4% AED), 1 in 50 (2% AED) and 1 in 100 year (1% AED) events, flood extents are similar for both scenarios with the exception that the 1 in 100 year (1% AED) extent is smaller in the region immediately west of Yatton.

The impact of raised defences on flood depth is evident to the north-west of Congresbury where depths recorded ‘with’ defences are over 0.75m lower for the 1 in 5 year (20% AED) event and shallower by 0.5m for the 1 in 100 year (1% AED) event. West of Congresbury average flood depths are lower for all return periods indicating the positive impact of raised defences in this region. The largest flood depths ‘with’ defences were recorded south-east of Congresbury; 4m for the 1 in 100 year (1% AED) event, more than double that of the ‘without’ defences scenario, suggesting that the raised defences are reducing the movement of water back into the channel and acting as bunds. Flood depths in this region were greater for all return periods in the ‘with’ defences scenario.

For Area 4, the defences at lower return periods lead to relatively extensive defended areas. The extent of defended areas decreases with increasing return period and at the 1 in 100 year (1% AEP) the defended areas are very limited with mapped extents for the undefended and defended areas being almost identical (see Figure 4.8). Given that the standard of protection along some of the raised defences is less than 1 in 100 years this is not unexpected.

Figure 4.8 suggests that the standard of protection for all of the defences in that area is less than 1 in 100 years. This is not the case. The majority of the flooding is not from overtopping of the 1 in 100 year defences but from areas of lower defences and adjacent watercourses. If these lower sections were improved then the standard of protection of 1 in 100 years for the area could be achieved without any changes to the rest of the defences in the area.

Figure 4.8: Area 4 Defended Areas



4.3.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

As this area has not been modelled and there are no raised defences, an assessment of the areas benefiting from defences has not been carried out.

5 IMPACT OF FLOODING

5.1 Speed of onset of flooding

The speed of onset of flooding is an important factor in flood management as a rapid onset of flooding increases risk to life. The speed of onset affects how much time people have to react to rising water levels and possible flooding. The speed of onset has been based on the time to peak calculations for the catchment hydrology and also on assessment of the hydraulic models (where appropriate) to determine the time of onset for a design event. This gives an indication of the time it could take following the peak of a rainfall event for flooding to occur at different return periods. In general as event severity increases, flooding will occur earlier and for longer. The study areas and their catchments have been classified into ranges according to the speed of onset. The ranges are given below:

- **Fast onset:** <1.5 hours time to peak
- **Moderate onset:** 1.5 – 4 hours time to peak
- **Slow onset:** >4 hours time to peak

Where tidal flooding is dominant over fluvial flooding it is considered a moderate onset.

5.1.1 Area 1: coastal strip from south of Clevedon to Ham Green

For the ‘without defences’ scenario, flooding occurs approximately 30 minutes prior to the peak of the first modelled tide for the 1 in 5 year event and 2 hours before the peak for the 1 in 200 year tide. When defences are accounted for within the model water overtops them for less time resulting in lower flood volumes.
The speed of onset of flooding is therefore moderate.

5.1.2 Area 2: urban extension area south-west of Bristol

Flooding starts to occur along both the Colliters Brook and Longmoor Brook at the QMED event, approximately 1.4 hours before the peak hydrograph for the equivalent event. For the 1 in 50 year (2% AEP) event, flooding starts to occur 1.8 hours before the peak of the hydrograph for the equivalent event along the Colliters Brook, and at 1.9 hours for the Longmoor Brook. These lead times are increased to just over 2 hours for the 1 in 100 year (1% AEP) event. The time to peak is approximately 5 hours for the Colliters Brook and Ashton Brook catchments.
The speed of onset of flooding is therefore moderate.

5.1.3 Area 3: land around Nailsea and Backwell

The northern and eastern models for the Nailsea area have been modelled in steady state which means that a constant inflow rather than a flood hydrograph has been used for the input data. However from analysis of the hydrology, the time to peak for the 1 in 100 year (1% AEP) event is 12 hours for the Land Yeo (northern model) and 4.5 hours for the un-named tributary within the eastern model. Whilst flooding may occur prior to the peak of the hydrograph, these timings provide an indication of the differences between the two catchments with regards to how they react to rainfall and the likely onset of flooding; we could assume that flooding would occur on the un-named tributary before on the Land Yeo (based on a catchment wide storm).

The speed of onset of flooding is therefore likely to be slow.

5.1.4 Area 4: land around Yatton/Congresbury

Flooding starts to occur along the Congresbury Yeo at the 1 in 5 year event, approximately 8.3 hours before the peak hydrograph for the equivalent event. Flooding at property boundaries starts to occur less than an hour before the peak hydrograph for the same event. At the 1 in 50 year event, flooding starts to occur just over 10 hours before the peak of the hydrograph with flooding at property boundaries 4.3 hours before the peak. These timings remain approximately the same for the 1 in 100 year event. The time to peak is approximately 11 hours for this catchment.
The speed of onset of flooding is therefore slow.

5.1.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

The time to peak for a 1 in 100 year (1% AEP) event varies from just over an hour for the Winscombe (middle) catchment to 6 hours for Wrington and 7 hours for the Banwell and Lower Langford catchments. This corresponds to the topography of this predominantly rural area where in the south of the area (Winscombe (middle) catchment) steep escarpment slopes exist and therefore rapid runoff conditions occur. Anecdotal evidence suggests that during the January 2008 floods in Wrington, the highest flood levels were present for at least 2 hours. The time interval between the peak of the rainfall event and the onset of flooding however will be 6 hours or less. Historic flooding suggests that the response in Wrington can be relatively quick. In conclusion, the speed of onset of flooding is fast for the Wrignton and Winscombe (middle) catchment and slow for the Banwell and Lower Langford catchments.

5.2 Flood Hazards

Flood Hazard Mapping brings information on flood depth and speed (velocity) of floodwater together to create a hazard rating for people for each area that experiences flooding. The hazard rating we have used is set out in the report Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk For New Development (FD2320/TR2) HR Wallingford (October 2005).

The hazard rating categorises flood risk in terms of Caution, Danger for Some, Danger for Most and Danger for All, with the hazard becoming dangerous to more kinds of people as depths and velocity increase. This is described in Table 5.1.

The Flood Hazard Mapping presented in this report is based on the hazard rating and colour coding as shown in Table 5.1 and is given below;

- Low flood hazard (green): **Caution**
- Moderate flood hazard (yellow): **Danger for Some** (includes children, elderly and the infirm)
- Significant flood hazard (orange): **Danger for Most** (includes the general public)
- Extreme flood hazard (red): **Danger for All** (includes the emergency services)

Table 5.1: Flood Hazard Matrix*

Velocity (m/s)	Depth (m)											
	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.00	green	green	green	yellow	yellow	yellow	orange	orange	orange	orange	red	red
0.10	green	green	green	yellow	yellow	orange	orange	orange	orange	orange	red	red
0.25	green	green	green	yellow	orange	orange	orange	orange	orange	red	red	red
0.50	green	green	green	orange	orange	orange	orange	orange	orange	red	red	red
1.00	green	green	yellow	orange	orange	orange	orange	red	red	red	red	red
1.50	green	green	yellow	orange	orange	orange	red	red	red	red	red	red
2.00	green	yellow	yellow	orange	orange	red	red	red	red	red	red	red
2.50	green	yellow	yellow	orange	red	red	red	red	red	red	red	red
3.00	green	yellow	yellow	red	red	red	red	red	red	red	red	red
3.50	green	yellow	orange	red	red	red	red	red	red	red	red	red
4.00	green	yellow	orange	red	red	red	red	red	red	red	red	red
4.50	yellow	yellow	orange	red	red	red	red	red	red	red	red	red
5.00	yellow	yellow	orange	red	red	red	red	red	red	red	red	red

*The hazard "Caution" (green) is not specified in FD2320/TR2 and has been employed within this SFRA to show maximum flood extent

Where the modelling used within this study is 1D, we do not have velocity and depth grids as model outputs that cover the areas of flood risk and have therefore based the degrees of flood hazard on estimates of velocity and depth grid mapping. However for areas where 2D modelling has been undertaken velocity and depth grids are produced as model outputs. To be consistent the hazard has not been mapped. Instead a general assessment has been made for the area.

5.2.1 Area 1: coastal strip from south of Clevedon to Ham Green

Considering the current situation and the presence of defences, tidal flooding is significantly reduced across the area especially to the south of Clevedon where there is no potential risk from a 1 in 200 year event. Defences are therefore sufficiently robust in this location. At Portishead and Portbury Wharf where the standards of protection are significantly lower, tidal inundation starts to occur at the 1 in 5 year return period or lower. As water depths are generally in excess of 1m and increase rapidly a significant to extreme risk would be experienced

If defences were to fail either through breaching or overtopping then locations such as Portbury Wharf and Kingston Pill, south of Clevedon could face extreme risk as depths of flooding could be in excess of 2.5m and there will be a rapid onset.. The majority of Portishead and the low lying ground to the east of Clevedon would be at moderate to significant hazard, the main differentiating factor being flood depth rather than flood velocity. Flow routes such as railways and highways may lead to a localised increase in flood water velocity but the predominant hazard with tidal flooding is rapid inundation and sheer volume of water leading to areas of extreme hazard due to potential flood depths.

5.2.2 Area 2: urban extension area south-west of Bristol

From assessment of the modelled results a moderate to significant flood hazard has been identified from the flood extent depths and average channel velocities. The main factor affecting the hazard is flood depth as the velocities are relatively low across the area.

As defences are not present within this area the assessment of hazards following breach or overtopping scenarios has not been assessed. The hazards have therefore been determined for the 1 in 100 year current scenario.

5.2.3 Area 3: land around Nailsea and Backwell

For the undefended situation the majority of the areas at risk of flooding within a 1 in 100 year event show a moderate to significant hazard due to relatively shallow depths of flooding of 0.25m to 1m to the eastern, southern and northern edges of Nailsea. To the north east of Backwell Common flood waters are deeper with the hazard classed as extreme. There are two locations (Cradle Bridge to the east, and north of Backwell Common to the south of Nailsea) where the hazard is also extreme due to the presence of water depths in excess of 2.5m.

From the broadscale modelling undertaken it is difficult to determine the likely hazards as a result of breach or overtopping. However as the standard of protection is relatively low along most of the sections of the channel where raised defences occur then it is likely that hazard ratings will be similar for both the undefended and defended situations as overtopping starts to occur at the QMED event (50% AEP).

5.2.4 Area 4: land around Yatton/Congresbury

For the current, defended situation flooding does occur at the 1 in 100 year event mainly across the predominantly agricultural land between Yatton and Congresbury and constitutes a low hazard rating. Flooding to the west of Congresbury is significantly reduced due to the presence of raised defences and therefore the hazard is deemed to be moderate.

If defences were to be breached or overtopped, the flooding at the 1 in 100 year event would be fairly extensive but would mainly provide a low flood hazard due to the relatively shallow depths and velocities involved particularly in the areas between Yatton and Congresbury. To the west of Congresbury the hazard would increase to moderate with small localised areas of significant hazard where flood water depths were greater than 0.4m.

5.2.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

As this area has not been modelled and therefore quantifiable information regarding depth and velocity across inundated areas is not available. However, flood depths of over 1.2m have been recorded in Banwell and Wrington, indicating a potential flood hazard of significant or extreme based on depth alone. If an integrated urban drainage model approach was followed for the Wrington catchment this model could be used to identify hazard ratings.

6 IMPACT OF CLIMATE CHANGE

Sensitivity testing for climate change within the fluvial modelling is represented by an increase in the 1 in 100 year flow of 20%. The impact of these increased flows on flood extents, depths and velocities has been assessed for the 1 in 100 year return period flows. A comparison has been made with the 1 in 100 year extents for the current situation. This is to allow us to assess the impact of an extreme flood event on the site now, and to use this as a baseline through which we can then make judgements about current flood risk and how this may change in the future with climate change.

For Area 1 and the assessment of future tidal flood risk, the extreme tide levels that were calculated by Royal Haskoning in 2003 (Report on Regional Extreme Tide Levels produced for the Environment Agency) have been used to take account of sea level rise for up to the next 200 years. This has been carried out with reference to the Defra FCDPAG3 Economic Appraisal Note to Operating Authorities – Climate Change Impacts October 2006, which equates to the following net sea level rise allowances for the South West of England:

- 3.5mm per year for 1990 to 2025
- 8.0mm per year for 2025 to 2055
- 11.5mm per year for 2055 to 2085
- 14.5mm per year for 2085 to 2115

Climate change allowance can produce dramatic changes in inundation in flat areas. Changes in the depth of flooding can have implications for the type of development that is appropriate, according to its vulnerability to flooding, due to the potential re-classification of the level of flood risk. With climate change predicting more frequent short-duration, high intensity rainfall and more frequent periods of long duration rainfall, surface water flooding is likely to be an increasing problem, particularly within urban areas as impermeability increases.

The assessment of climate change has been made using the ‘without defences’ scenario which follows the flood extent mapping as depicted by the Environment Agency within their Flood Zone 3 mapped extents.

6.1 Flood Extents

6.1.1 Area 1: coastal strip from south of Clevedon to Ham Green

A very limited increase in flood extents has been identified in this area as a result of climate change. Therefore the lateral extents are relatively similar to those without climate change largely due to the relatively high potential inundation that occurs at lower return periods.

6.1.2 Area 2: urban extension area south-west of Bristol

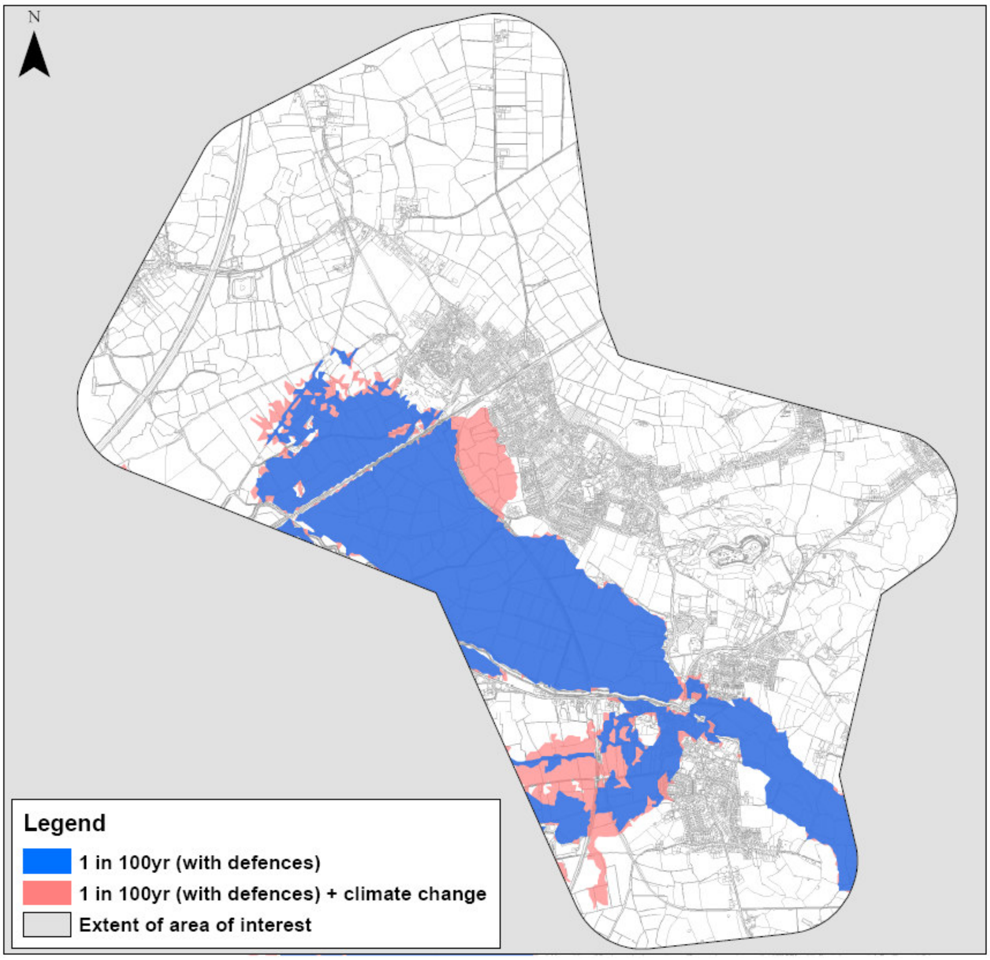
A 20% increase in flows has no impact on flood extents to the west of the area at Ashton Brook. In relation to the Longmoor and Colliters Brooks, increases in flood extents were minimal, expanding by less than 20m laterally along the southern edges of the flooded area.

6.1.3 Area 3: land around Nailsea and Backwell

A 20% increase in flows has limited impact on flood extents for both the northern and eastern models. This is not unexpected given the low standard of protection along certain stretches of the watercourses and the potentially extensive inundation that occurs at these low return periods.

6.1.4 Area 4: land around Yatton/Congresbury

Figure 6.1: Mapped flood extents with climate change



As shown in Figure 6.1 above, a 20% increase in flows results in an increase in lateral extents of up to 350m to the south west of Yatton and additional more patchy areas of flooding to the west of Yatton. To the west of Congresbury and south of the Congresbury Yeo the flood extents have increased by 100% with predominantly agricultural land affected though a number of minor roads are also inundated.

6.1.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

As this area has not been modelled quantifiable information regarding the effect of a 20% increase in flows has not been carried out. Whilst we would not anticipate an extensive increase in lateral flow extents we would expect climate change to have an impact on the severity of flood risk exacerbating the impacts of flooding.

6.2 Flood Depth

6.2.1 Area 1: coastal strip from south of Clevedon to Ham Green

The maximum water elevations for the 1 in 200 year event plus climate change have increased by 200mm in the south western area of the site and by 1000mm along the Clevedon coastline.

6.2.2 Area 2: urban extension area south-west of Bristol

As there is limited impact on increased flood extents over the site itself, the overall increase in depth is not extensive. Maximum water elevations for the 1 in 100 year event plus climate change have increased by 0.1m in the region of flooding between Longmoor and Colliters Brook and by approximately 0.25m in the area to the east of Colliters Brook.

6.2.3 Area 3: land around Nailsea and Backwell

There is virtually no change in the extents of flooding as a result of increased flows and therefore the increase in the depth of flooding over the model area is very limited and less than 0.1m.

6.2.4 Area 4: land around Yatton/Congresbury

A 20% increase in flows predominantly results in an increase in depth of less than 0.1m. However there are a few more localised areas of greater depth increase of 0.2m to the east of Yatton, south of the railway line and up to 0.45m to the south east of Yatton in an area that only experiences flooding as a result of climate change.

6.2.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

As this area has not been modelled quantifiable information regarding the effect of a 20% increase in flows has not been carried out. Whilst we would probably not anticipate an extensive increase in the depth of flooding we would expect a marginal increase to occur.

6.3 Flood Velocity

6.3.1 Area 1: coastal strip from south of Clevedon to Ham Green

The mean increase in maximum velocity as a result of increased flows for the 1 in 200 year return period including climate change is between 0.2 and 0.45m/s at a number of locations within this region.

6.3.2 Area 2: urban extension area south-west of Bristol

Ashton, Longmoor and Colliters Brooks comprise very small channels which show little variance in velocity across all return periods, the effect of increased flows due to climate change is therefore expected to be small. In-channel velocities display minor differences, for example velocities in Longmoor Brook show an increase of 0.013m/s with a 20% increase in flow.

6.3.3 Area 3: land around Nailsea and Backwell

Maximum velocities at a number of sample locations within the northern and eastern models increase by an average of 5% to 8% as a result of a 20% increase in flows.

6.3.4 Area 4: land around Yatton/Congresbury

A 20% increase in flows has no impact on flood velocities in the area surrounding Yatton and Congresbury.

6.3.5 Area 5: land around Banwell/Winscombe/Churchill/Wrington

As this area has not been modelled quantifiable information regarding the effect of a 20% increase in flows on velocity has not been carried out.

7 SITE SUMMARY TABLES

This section contains a summary table for each of the 5 areas investigated in this Level 2 summary. This is then followed by some general comments and guidance.

7.1 Area 1 – Coastal strip from south of Clevedon to Ham Green

Flood risk (with defences)		High flood risk at Portbury Dock area otherwise risk of tidal flooding low.	
Speed of onset[1] (with defences)		Moderate	
Hazard rating[2] (with defences)		Significant to Extreme at Portishead and Portbury. Remaining area no flooding with defences. However residual risk if breach/failure/design exceedence.	
Defences and mitigation measures	**Current**	Potential for overtopping high at Portbury Dock area (SoP[3] 1 in 5 years). Good standard of defence south of Clevedon (SoP 1 in 200 years). Unknown existing defence standard means difficult to determine impact of defences in reducing risk.	
	Future (100yrs)	Sea level rise will increase water levels up to 1m. Generally assumed that tidal defence crests will need to increase to retain current level of protection. Uncertainty over current SoP of some tidal defences makes future adequacy difficult to determine.	
Proposed site 1: Portbury Wharf and adjacent to existing Portishead marina		**Proposed development**	0.6km^2 of residential development planned adjacent to tidal flood risk areas.
		Potential for proposed development	Low. Exception Test required due to FZ3a. Some FZ1 areas but access and egress during flooding problematic particularly when climate change is considered. Climate change does not alter extents significantly.
		PPS25 / FRA requirements for NSC	Review of existing defence standards required with possible improvements necessary. Improvements to access and egress needed to satisfy Exception test. Runoff from new development would be within existing tidal flood extents; ensure outfalls not tide locked.
		Core Strategy recommendations for NSC	Strategic review of existing defences standards required as many ‘unknown’ and therefore difficult to determine development potential. Consider a strategic review of existing and required drainage to facilitate proposed development. Core strategy should consult and reference currently ongoing review of the Shoreline Management Plan.
Proposed site 2: Charlcombe Wood		**Proposed development**	Assumed residential
		Potential for proposed development	High: FZ1 & climate change does not alter extents significantly.

	PPS25 / FRA requirements for NSC	If developments are over 1 hectare a FRA will be required along with exemplar drainage scheme through SUDS.
	Core Strategy recommendations for NSC	Based on flood risk, this is a good site for development and should be promoted.
Proposed site 3: Moor Farm	**Proposed development**	Assumed residential
	Potential for proposed development	Low. Exception test required – FZ3a. Climate change does not have a significant impact.
	PPS25 / FRA requirements for NSC	Review of existing defence standards required with possible improvements necessary to satisfy Exception Test.
	Core Strategy recommendations for NSC	Strategic review of existing defences standards required as many 'unknown' and therefore difficult to determine development potential. Core strategy should consult and reference currently ongoing review of the Shoreline Management Plan.
Proposed site 4: Adjacent to Royal Portbury Dock	**Proposed development**	Railway Station (PPS25: Essential transport infrastructure)
	Potential for proposed development	Low. Exception test required (fluvial FZ 3b – functional floodplain).
	PPS25 / FRA requirements for NSC	Exception Test would be required for proposed development. Access and egress needs to be considered. Essential infrastructure and water compatible uses should only be permitted if the scheme has been designed and constructed to remain operational and safe during floods, result in no net loss of functional floodplain, not impede water flows and not increase flood risk elsewhere.
	Core Strategy recommendations for NSC	Core strategy should clearly set out the need for essential infrastructure at this site. Flood defence infrastructure may be required.
Proposed site 5: Infill	**Proposed development**	Assumed residential in Portishead area
	Potential for proposed development	Low, Exception test required – tidal FZ3a
	PPS25 / FRA requirements for NSC	Review of existing defence standards required with possible improvements necessary to satisfy Exception Test. Drainage impacts would need to be considered.
	Core Strategy recommendations for NSC	Develop planning policy approach for infill sites in relation to Flood Risk Management (including surface water flood risk). See general comments.

Speed of onset[1]: based on categories outlined in Section 5.1
Hazard Rating[2]: based on categories from Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk For New Development (FD2320/TR2) HR Wallingford (October 2005).
SoP[3]: Standard of protection (years)

7.2 Area 2 – Urban extension area south-west of Bristol

<table>
<tr><td colspan="2">Flood risk
(with defences)</td><td colspan="2">No defences but flood risk not significant until 1 in 20 year event. Area of flooding relatively small. High tides in River Avon can result in tide-locking.</td></tr>
<tr><td colspan="2">Speed of onset[1]
(with defences)</td><td colspan="2">Moderate</td></tr>
<tr><td colspan="2">Hazard rating[2]
(with defences)</td><td colspan="2">Moderate to significant</td></tr>
<tr><td rowspan="2">Defences and mitigation measures</td><td>Current</td><td colspan="2">No raised defences present. NFCDD shows maintained channel with culverted sections (outside of model extent).</td></tr>
<tr><td>Future (100yrs)</td><td colspan="2">Development could increase surface water run-off by 5-11%. This would need to be considered in mitigation design. Ensure flood storage incorporated into south-west urban extension.</td></tr>
<tr><td colspan="2" rowspan="4">Proposal:
$3km^2$ of development planned within the upper Ashton Brook catchment.</td><td>Proposed development</td><td>Residential (South west urban extension to Bristol, redevelopment of Long Ashton Research Centre, redevelopment of Barrow hospital site)</td></tr>
<tr><td>Potential for proposed development</td><td>High - All sites outside of existing FZ3 & FZ2 and climate change not thought to have an impact on extents. Climate change extents would need to be confirmed prior to development being approved.</td></tr>
<tr><td>PPS25 / FRA requirements for NSC</td><td>Site specific FRAs necessary for development over 1 hectare in size.
Final flood zone 3a and 3b classification at Ashton Vale to be considered when applying the Sequential Test (Flood map challenge underway at time of writing report).
Existing Ashton Vale infrastructure will require improving to enable development.</td></tr>
<tr><td>Core Strategy recommendations for NSC</td><td>Create policy for use of SUDS particularly in relation to this area.
Create policy to create amenity and recreational uses into flood storage area(s).
Recommend strategy to review existing flood scheme. Seek improvements to the scheme through new development that will also benefit existing development.
Create policy to improve flood risk management infrastructure. Develop a Supplementary Planning Document on tariffs to determine how costs will be accumulated.</td></tr>
</table>

Speed of onset[1]: based on categories outlined in Section 5.1
Hazard Rating[2]: based on categories from Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk For New Development (FD2320/TR2) HR Wallingford (October 2005).
SoP[3]: Standard of protection (years)

7.3 Area 3 – Land around Nailsea and Backwell

<table>
<tr><td colspan="2">Flood risk
(with defences)</td><td colspan="2">Relatively high flood risk due to low return period of onset of flooding.</td></tr>
<tr><td colspan="2">Speed of onset[1]
(with defences)</td><td colspan="2">Slow</td></tr>
<tr><td colspan="2">Hazard rating[2]
(with defences)</td><td colspan="2">Moderate to Significant with isolated areas of Extreme</td></tr>
<tr><td rowspan="2">Defences and mitigation measures</td><td>Current</td><td colspan="2">Potential for overtopping at low return periods but mainly agricultural land inundated. Some isolated properties at risk.</td></tr>
<tr><td>Future (100yrs)</td><td colspan="2">No significant increase in inundation with projected 20% increase in flows.</td></tr>
<tr><td colspan="2" rowspan="4">Proposal:
No major developments proposed so development like to be infill.</td><td>Proposed development</td><td>Assumed residential</td></tr>
<tr><td>Potential for proposed development</td><td>Depends on site and location. Provided infill is away from areas of flood risk then potential is high. Climate change not thought to have a significant impact.</td></tr>
<tr><td>PPS25 / FRA requirements for NSC</td><td>Current defences on Land Yeo and unnamed tributary are generally low. Development behind these defences would not meet criterion C of Exception Test. Sequential Test should be applied to find sites outside of FZ 3 and 2 in the first instance. Infill development in flood risk areas will require improvements to existing defences.</td></tr>
<tr><td>Core Strategy recommendations for NSC</td><td>Develop planning policy approach for infill sites in relation to Flood Risk Management (including surface water flood risk).
If a number of infill sites are likely within Flood Zone 2 or 3, a strategic approach to improving existing defences may be prudent to secure improvements for existing properties.
Recent incidents of flooding from insufficient drainage and surface water suggest need for Surface Water Management Plans to identify improvements to existing infrastructure and guide new infill development in and around both villages.</td></tr>
</table>

Speed of onset[1]: based on categories outlined in Section 5.1
Hazard Rating[2]: based on categories from Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk For New Development (FD2320/TR2) HR Wallingford (October 2005).
SoP[3]: Standard of protection (years)

7.4 Area 4 – Land around Yatton / Congresbury

Flood risk (with defences)		Flooding is extensive but shallow, though risk is relatively high due to low return period of onset	
Speed of onset[1] (with defences)		Slow	
Hazard rating[2] (with defences)		Low for land between Yatton and Congresbury. Moderate to the west of Congresbury	
Defences and mitigation measures	**Current**	Potential for overtopping at low return periods, but mainly agricultural land inundated.	
	Future (100yrs)	Increased properties at risk in Congresbury in future therefore improvements to existing defences recommended.	
Proposed site 1: Small areas to the north of Yatton		**Proposed development**	Assumed residential
		Potential for proposed development	Low - 2 sites in current FZ3b – functional floodplain. Only water compatible development allowed. 1 site will be in FZ 3 in the future through climate change – low potential, Exception Test required.
		PPS25 / FRA requirements for NSC	Current defences on Congresbury Yeo at varying standards. Would not meet criterion C of Exception Test. Sequential Test should be applied to find sites outside of FZ 3 and 2 in the first instance. Infill development in flood risk areas will require improvements to existing defences.
		Core Strategy recommendations for NSC	Develop planning policy approach for infill sites in relation to Flood Risk Management (including surface water flood risk). If a number of infill sites are likely within Flood Zone 2 or 3, a strategic approach to improving existing defences may be prudent to secure improvements for existing properties.
Proposed site 2: Small areas south of Congresbury		**Proposed development**	Assumed residential
		Potential for proposed development	Moderate – small area of site in FZ3a – will need Exception Test if whole site to be developed. Impacts of climate change need to be understood in more detail for this area prior to development.
		PPS25 / FRA requirements for NSC	Exception Test would be required for proposed development. No net loss of function floodplain allowed. Access and egress needs to be considered taking climate change into account. More investigation required into the impacts of climate change.
		Core Strategy recommendations for NSC	Develop planning policy approach for infill sites in relation to Flood Risk Management (including surface water flood risk).

Speed of onset[1]: based on categories outlined in Section 5.1
Hazard Rating[2]: based on categories from Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk For New Development (FD2320/TR2) HR Wallingford (October 2005).
SoP[3]: Standard of protection (years)

7.5 Area 5 – Land around Banwell / Winscombe / Churchill / Wrington

Flood risk **(with defences)**		Extensive surface water flooding in certain locations such as Wrington.
Speed of onset[1] **(with defences)**		Fast for Winscombe and Wrington, Slow for Churchill and Land around Banwell
Hazard rating[2] **(with defences)**		N/A
Defences and mitigation measures	**Current**	N/A
	Future (100yrs)	Consider integrated urban drainage approach to identify potential mitigation options and creation of SWMP for Wrington.
Proposed: No major developments allocated under LDF	**Proposed development**	Assumed residential
	Potential for proposed development	Depends on site and location. Provided development is away from areas of known surface water flooding problems then potential is high.
	PPS25 / FRA requirements for NSC	Address existing and future surface water risks. Creation of a SWMP for Wrington to deliver integrated drainage would assist clustered infill development.
	Core Strategy recommendations for NSC	Develop planning policy approach for infill sites in relation to Flood Risk Management (including surface water flood risk).

Speed of onset[1]: based on categories outlined in Section 5.1
Hazard Rating[2]: based on categories from Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk For New Development (FD2320/TR2) HR Wallingford (October 2005).
SoP[3]: Standard of protection (years)

7.6 General comments

Listed below are some suggestions for inclusion in a planning policy approach for infill sites in relation to Flood Risk Management:

- Approximate locations and quantities of infill development appropriate for each area.
- Application of the Sequential Test to locate sites.
- Method to determine trigger of strategic flood risk management / drainage / SWMPs measures to guide development (includes sites allocated according to the Sequential test)
- Clear direction for planners on the required content of a FRA (refer to NSC Level 1 SFRA)

Where the Exception test needs to be applied the following should be considered:

- The approach to determining responsible authority for improving existing infrastructure and improving flood risk management measures, including guidance for seeking developer contributions.
- The strategy for provision of flood warnings and inclusion in emergency planning procedures
- Clear direction for planners on the required content of a FRA (refer to NSC Level 1 SFRA)

8 CONCLUSIONS

This SFRA has been used to assess the flood risk to five areas highlighted by North Somerset Council in accordance with PPS25.

A significant number of the areas reviewed have areas of Flood Zone 3a and 3b, which means that they are at least partially unsuitable for development without significant mitigation measures. An indication of the extent of these zones was provided in the Level 1 SFRA. The extent of these zones can be challenged via a site specific Flood Risk Assessment (FRA) by a developer if more detailed modelling becomes available. This will then need to be agreed with the Environment Agency.

The confirmation of areas at risk of flooding and measures to reduce flood risk, as highlighted by a FRA, is very important to ensure new development is not at unacceptable risk of flooding in the future and that flood risk is not increased elsewhere. The level of detail for each FRA will vary depending on the risk to that area. Guidance to both planners and developers is given in this Level 2 SFRA and the North Somerset Level 1 SFRA.

Where mitigation works will be required for development it is recommended that when requesting an FRA from developers North Somerset Council ask that the possible reduction of existing flood risk is investigated. This could be achieved through Section 106 Agreements. These agreements can act as a main instrument for achieving wider objectives, often requiring developers to minimise the impact on the local community and to carry out tasks which will provide community benefits.

Where possible North Somerset Council should seek opportunities for combined strategic mitigation measures which may provide a wider benefit than piecemeal development based measures. This could result in the flood risk to existing properties being reduced as well as providing defended land for the development. In addition strategic drainage measures e.g. SUDS can be much more effective over a large area rather than small individual development based schemes. Developer contributions could then be investigated via Section 106 Agreements for the installation and possible maintenance of the defences and/or SUDS.

Under PPS25 North Somerset Council should apply the sequential test in terms of flood risk when considering sites proposed for development. This means that sites of little or no flood risk should take preference over sites where flood risk could be an issue. Royal Haskoning recommend, however, that the sequential test be applied in conjunction with opportunities to reduce existing flood risk. Each of the developer’s plans should therefore be reviewed in relation to their flood risk and their potential to improve existing problems.

Where there are areas of flood risk within proposed development sites the sequential test should also be applied when specifying the Master Plan for the site. This will ensure that any highly vulnerable uses are directed to the areas of lower flood risk, whilst the lower vulnerability or water compatible uses can be placed within the higher risk areas. Safe access and egress should also be considered when reviewing the flood risk to the proposed site.

For any proposed development within flood risk areas flood warnings should be considered and included as part of the planning application. The impact of the development should also be considered in terms of the existing Flood Warnings for the area.

In order to meet exception test climate change needs to be considered for the lifetime of the development, particularly when considering mitigation measures required. If existing defences exist, then for development to be permitted, these will need to be maintained at required standard for lifetime of development. This is of particular relevance to tidal defences due to sea level rise. It is highly likely that to maintain the required standard of protection defences may need to be raised at some point during the lifetime of the development. It is therefore recommended that a programme is put in place for this maintenance and improvement works along with details of funding.

GLOSSARY OF TERMS

ABD	Areas Benefiting from Defences
AEP	Annual Exceedence Probability. The estimated probability of a flood of given magnitude occurring or being exceeded in any year.
Catchment	The area contributing surface water flow to a point on a drainage or river system (the area drained by that river, including areas away from the watercourse network). Can be divided into sub-catchments.
DEM	Digital Elevation Model
Design Event	A historic or notional flood vent of a given annual flood probability, against which the suitability of a proposed development is assessed and mitigation measures, if any are designed.
DTM	Digital Terrain Model
EA Flood Zone 1	Low Probability of flooding
EA Flood Zone 2	Medium Probability of flooding. Probability of fluvial flooding is 0.1 – 1% and probability of tidal flooding is 0.1 – 0.5%
EA Flood Zone 3a	High Probability of Flooding. Probability of fluvial flooding is 1% (1 in 100 years) or greater and probability of tidal flooding is 0.5% (1 in 200 years) or greater.
EA Flood Zone 3b	Functional floodplain.
Environment Agency (EA)	Non-departmental public body responsible for the delivery of government policy relating to the environment and flood risk management in England and Wales.
FAS	Flood Alleviation Scheme
FEH	Flood Estimation Handbook. The Environment Agency approved method of estimating flood flows in the UK.
Flood Defence	A structure (or system of structures) for the alleviation of flooding from rivers or the sea to a specified design standard.
Flood Estimation Handbook	The Environment Agency approved method of estimating flood flows in the UK.
Flood Risk	The level of flood risk is the product of the frequency or likelihood of the flood events and their consequences (such as loss, damage, harm, distress and disruption).
Flood Risk Assessment	Considerations of the flood risks inherent in a project, leading to the development of actions to control, mitigate or accept them.
Floodplain	Any area of land over which water flows or is stored during a flood event, or would flow but for the presence of flood defences.
Fluvial	Pertaining to a watercourse (river or stream).
Freeboard	The difference between the design flood level and the lowest point on the flood defence.
FRM	Flood Risk Management: the activity of modifying the frequency or consequences of flooding to an appropriate level (commensurate with land use), and monitoring to ensure that flood risks remain at the proposed level. This should take account of other water level management requirements, and opportunities and constraints.

GIS	Geographical Information System. A computer-based system for capturing, storing, checking, integrating, manipulating, analysing and displaying data that are spatially referenced.
Greenfield runoff rate	The rate of runoff that would occur from the site in its undeveloped state.
Groundwater	Water occurring below ground in natural formations (typically rocks, gravels and sand).
Hazard	A situation with the potential to result in harm. A hazard does not necessarily lead to harm.
Hydraulic model	A computerised model of a watercourse and floodplain to simulate water flows in rivers to estimate water levels and flood extents.
iSIS	One dimensional hydraulic modelling software.
Main River	Watercourses defined on a 'Main River Map' designated by DEFRA. The Environment Agency has permissive powers to carry out flood defence works, maintenance and operational activities for Main Rivers only.
QMED	Mean annual maximum flood
mOD	Metres Ordnance Datum. Elevations use Ordnance Datum Newlyn.
NFCDD	National Flood & Coastal Defence Database. Environment Agency asset management system database.
PPS25	Planning Policy Statement 25; 'Development and Flood Risk'.
Probability	The likelihood of an event occurring.
Residual Flood Risk	The remaining flood risk after risk reduction measures have been taken into account.
Return Period	The average time period between rainfall or flood events with the same intensity and effect.
SLR	Sea Level Rise.
Standard of protection	The level of flood that a defence is designed to protect against before it is exceeded.
Surface Runoff	Water flowing over the ground surface to the drainage system. This occurs if the ground is impermeable, is saturated or if rainfall is particularly intense.
Sustainable Drainage Systems (SUDS)	A sequence of management practices and control structures designed to drain surface water in a more sustainable fashion than some conventional techniques.
Time to peak	The time from the centroid of the total rainfall to the peak of the runoff hydrograph, i.e. the length of time it takes to convert rain into river flow.
Topography	The shape and form of the land, in terms of hills, steepness of slopes, or flat land.

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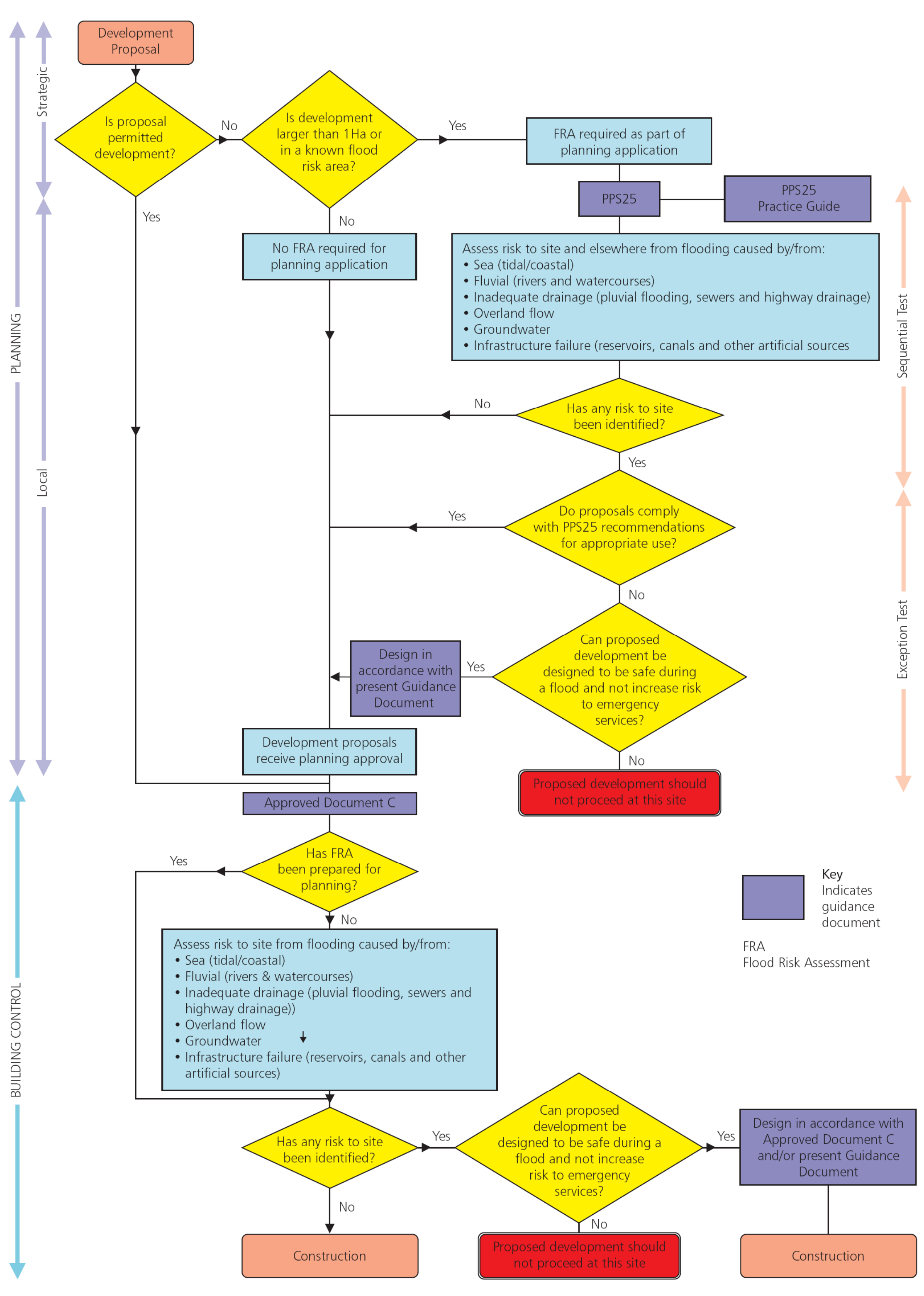
Appendix A

Guidance for site specific FRAs, the use of SUDs techniques and Flood Resilient Construction

FRA Decision tree and minimum criteria for assessment

Figure 3.2 Decision tree for planning process and building control



Source: Improving the performance of New Buildings: Flood Resilient Construction (Communities and Local Government 2007)

If an FRA is required then the following tick sheet can be used to assess if the minimum criteria have been met…

FRA Criteria	**Included in the FRA?***	**Significant impact?****
Of appropriate detail for the size of the development and risk involved.		
Consider the risk to the development.		
Consider the risk to the surrounding as a result of the development.		
Consider the impacts of climate change.		
Be undertaken by competent people at an early stage in the planning process.		
Consider both the beneficial and adverse effects of any flood risk management infrastructure, along with the consequences of their failure.		
Consider the vulnerability classification of the people who will use the site.		
Put in place safe access to and from the site in times of flood.		
Consider and quantify the existing flood risk from all sources.		
Identify possible measures to reduce the flood risk.		
Consider the effects of a range of flood events on people, property, the natural and historic environment and rivers & coastal processes.		
Include an assessment of the residual risk after flood risk management infrastructure has been put in place and demonstrate that this is acceptable for the development in that particular flood zone.		
Consider how the development may affect how water drains into the ground.		
Consider the effect the proposed development layout may have on the drainage systems.		
Be supported by appropriate data, including historical information on previous events.		

* If any of these are not included in the FRA, return it to the developer for further information.
** If any of these highlight that the impact is significant then further investigation may be required.

If the Exception test is required then more information will need to be collected and analysed.

Surface Water and Sustainable Drainage Systems (SUDS)

Flood risk from surface water flooding is of concern within the study area. A number of flood incidents have occurred within the area caused by surface water alone, or in combination with river flooding. Some of these events are highlighted on the maps as recorded by the EA (FRIS) or historic information. The EA Flood Zone Maps do not show flood risk due to surface water flooding.

Urban developments can have a big effect on the quantity and speed of surface water runoff. By replacing vegetated ground with buildings and paved areas, the amount of water being absorbed into the ground is severely reduced, therefore increasing the amount of surface water present. This additional surface water increases the demand on drainage systems in built up areas. Traditional drainage systems are designed to get rid of the water as quickly as possible to prevent flooding in the built up area. This can cause problems, particularly downstream, by altering the natural flow patterns of the catchment. In addition, water quality can be affected due to pollutants from the built up areas being washed into the watercourse. One technique which can reduce this problem is the use of Sustainable Drainage Systems (SUDS).

Sustainable Drainage Systems (SUDS) are techniques designed to control surface water runoff before it enters the watercourse. They are designed to mimic natural drainage processes, along with treating the water to reduce the amount of pollutants getting into the watercourse. They can be located as close as possible to where the rainwater falls and provide varying degrees of treatment for the surface water, using the natural processes of sedimentation, filtration, adsorption and biological degradation.

SUDS are more sustainable than traditional methods because they can:

- Manage the speed of the runoff
- Protect or enhance the water quality
- Reduce the environmental impact of developments
- Provide a habitat for wildlife
- Encourage natural groundwater recharge.

In addition, they can be used to create more imaginative and attractive developments and are designed so that less damage is done, than conventional systems, if their capacity is exceeded.

Surface water management using SUDS can be implemented at all scales and in most urban settings, ranging from hard-surfaced areas to soft landscaped features, even if there is limited space. Most techniques use infiltration but even if the area has little or no infiltration SUDS can still be used in the form of green roofs, permeable surfaces, swales and ponds.

SUDS are made up of one or more structures built to manage surface water runoff, and used in conjunction with good site management. There are five general methods:

a. **Prevention** – this can involve minimizing paved areas, replacing tarmac with gravel, rainwater recycling, cleaning and sweeping, careful disposal of pollutants, and general maintenance.

b. Filter strips and swales – these are vegetated surface features that drain water more slowly and evenly off impermeable areas. Swales (figure 4.2) are long shallow channels whilst filter strips (figure 4.3) are gently sloping areas of ground. Both of these mimic natural drainage by allowing rainwater to run in sheets through vegetation, slowing and filtering the flow.

Figure 4.2 - Cross-section of a Swale

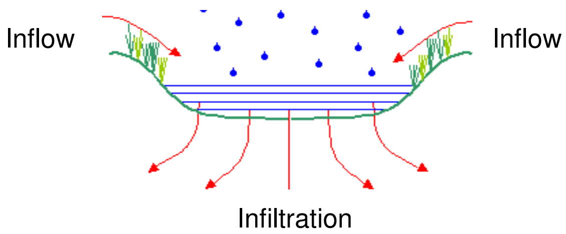
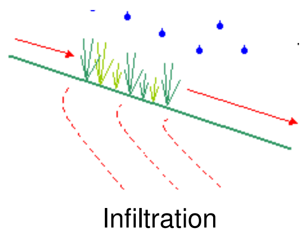


Figure 4.3 - Cross-section of a Filter Strip



c. Permeable surfaces and filter drains – these are devices that have a volume of permeable material below ground to store surface water. Runoff flows to this storage area via a permeable surface. On 2nd April 2008 the BBC's One show examined the effects of permeable paving on surface water runoff during heavy rainfall. This can be viewed via the BBC website.

d. Infiltration devices – these enhance the natural capacity of the ground to store and drain water. They include soakaways, infiltration trenches and infiltration basins. See figure 4.4.

e. Basins and ponds – these are areas for storage of surface runoff e.g. floodplains, wetlands, and flood storage reservoirs. They can be designed to control flows by storing water then releasing it slowly once the risk of flooding has passed. See figure 4.5.

Figure 4.4 - Cross-section through an Infiltration Basin

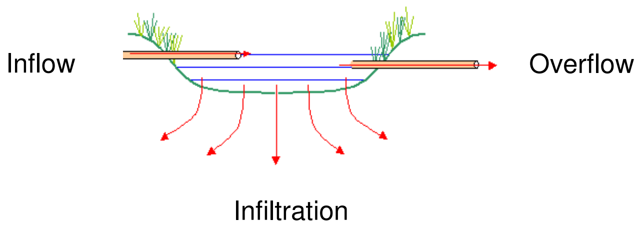
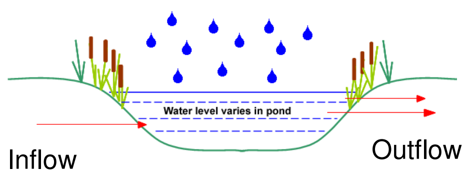


Figure 4.5 - Cross-section of a Pond



Water level varies in the pond

Surface water flooding appears to be a problem across the whole of the MDC area, except on the Mendip Hills to the north of the study area. There is some clustering of incidents around the wards of Beacon, Avalon, Glastonbury and Shepton Mallet but no one area stands out as having a significant surface water flooding problem.

SUDS are better suited to areas of new development than in-fill. This is because for new development the drainage system for the whole area can be considered and designed at the same time, ensuring a consistent system across the development area and surroundings. Retro-fitting produces pockets of SUDS which work in isolation and therefore are not as effective as they could be within a SUDS strategy.

It is imperative that when designing SUDS for an area that both the EA and the local drainage board are consulted at all stages of the design. This will ensure that the SUDS fit with the existing drainage network.

SUDS need to be regularly maintained to ensure they operate efficiently and effectively. The maintenance regime should be detailed and agreed during the design stage. Different SUDS techniques require different levels of maintenance therefore it is important to make it clear who is responsible for the maintenance at the start of the design and put a programme in place.

Government Guidance has been produced in the new water strategy for England, *Future Water,* which was published in February 2008. This strategy sets out the Government's long-term vision for water management in England. Following this publication, a consultation is currently underway (and due to finish 30th April 2008) regarding policy measures to improve the way that surface water runoff is managed. One of the suggested management tools is the development of Surface Water Management Plans. When completed, these should provide useful guidance for developers and local authorities. More information regarding these strategies and plans can be found on the Defra website (www.defra.gov.uk/Environment/water/strategy/index.htm).

Guidance for developing housing in a flood resistant manner

PPS 25 states that development situated in EA Flood Zones 2 or 3 may be required to be built using flood resistant construction.

Exterior Construction
There are several measures to improve flood resistance of a wall using mortar, sealants and fillers. These measures include applying waterproof sealant to the outside face (ideally a breathable sealant), raising the level of the damp proof course, injection of fillers, closing cavities and ensuring there are no cracks or voids in the brickwork.

Excluding water will help reduce damage to the internal fabric of the building and its contents. If water does enter the house, flood resistant building materials will reduce the effects of the water and can reduce the cost of repairs.

Interior Construction
One of the most effective ways of reducing the impact of flooding is to raise the floor level of the property above expected flood levels. If this is not practical, another is to have flooring that can withstand being under water. Chipboard flooring is likely to be damaged by floodwater, so more resistant materials such as treated floorboards, WBP plywood, screed or tiles will be more suitable in flood risk areas. Fixtures that cannot be removed before a flood and might be damaged by exposure to water, such as carpets, parquet and laminate wooden floors should be avoided.

Where internal flooding cannot be avoided, some form of drainage of the water immediately post flood is recommended. In addition to protecting flooring, utility supplies should also be protected so that they can still be used in the event of internal property flooding.

- Electricity
  If there is sufficient space, the meter and fuse box should be positioned at a level which is higher than the expected flood level.
  Modern wiring is not usually affected by flooding, but long immersion may result in the need to replace wiring. Moving the ground floor ring main cables to first floor level could be considered with drop down cables to ground floor sockets. Sockets should also be raised to an appropriate height above flood levels. A further consideration is to have the house wired so that the ground floor main can be switched off, leaving the supply to the upper floors still available.

- Gas supply
  As gas meters can be affected by floodwater it is worth considering raising meters above the expected flood levels. Provision should be made for purging gas supply pipes through the installation of appropriate valves and drain points.

- Central heating systems
  Gas and oil fired boilers and associated pumps and controls should preferably be installed above the maximum expected flood level. Pipe insulation below the expected flood level should preferably be replaced with closed cell insulation. If new heating is being installed, pipework routes should be made easily accessible to allow pipes to be maintained and washed down following flooding.

- Water supply
  Water pipework insulation can be replaced with flood resistant closed cell material below the expected flooding level.

- Telephone and cable services
  Suppliers of the relevant services should be consulted on suitable installation methods in areas liable to flooding. Where possible, incoming telephone lines and internal control boxes should be raised above the expected flood levels.

- Oil storage tanks
  Oil tanks can be damaged during floods and can cause pollution. To avoid this it should be ensured that the tank is anchored down so that it does not float. In addition the oil feed from the tank should incorporate a stop valve at the end nearest the tank so that the tank contents will not be lost if the tank moves and the pipe breaks.

The information above is a summary of the CIRIA Advice Sheets. All the advice sheets, and further guidance for homeowners and developers, can be downloaded from http://www.ciria.org/flooding/advice_sheets.html

In addition, the recently released *Improving the Flood Performance of New Buildings: Flood Resilient Construction,* May 2007, Department for Communities and Local Government provides additional useful information, particularly for properties in low or residual flood risk areas. This can be found at http://www.floodforum.org.uk/improvingfloodresilienceofnewbuildings.pdf

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Appendix B

Approximate costs for improving the existing standard of protection

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Approximate costs for improved existing standard of protection

During our assessment we highlighted a number of areas of defence that were below the required standard of protection, and therefore putting existing properties at risk. Set out below are details of the indicative costs that may be required to bring these defences up to the required standard. We have estimated these costs using a large number of assumptions. We would therefore expect these costs to only provide a ball-park figure. A detailed assessment / feasibility study investigating the existing defences and the additional heights required would need to be undertaken to establish a better estimate of the costs involved. This would also need to look at the benefits to determine if raising the defences is economically justified.

During this assessment we have made the following assumptions:

- The *Flood Risk Management Estimating Guide, Unit Cost Database 2007* report and the *Flood Risk Area (F.R.A) Prioritisation Unit Cost Estimating Handbook, March 2004* has been used to aid our assessment of the approximate costs for raising the height of the existing defences.
- Areas where there are existing properties at risk have been investigated. Around Nailsea the properties at risk are generally isolated properties and therefore individual property protection would be more viable. We have therefore only assessed the cost of raising defences for Areas 1 and 4.
- Only existing defences have been considered. No new defences or defence lines have been assessed; therefore we are assuming the current defence line is the most appropriate.
- The condition of the structures is not known (based on NFCDD) and therefore it is assumed that they are condition 3, fair. It is therefore assumed that the earth structures are suitable for raising. For reinforced concrete structures it has been assumed that the foundations are not adequate for the new height required. This may not be the case for all the assets and a detailed asset survey would be required as part of a feasibility study.
- No specific costs have been included to account for gaining access to the assets, land procurement etc.
- An inflation rate of 5% from March 2006 to September 2009 has been assumed within our calculations to bring the cost up to 2009 prices.
- Where the asset is an embankment we have assumed that increasing the footprint width to maintain the required crest width and slope. A crest width of 4m and a slope of 1 in 3 has been assumed.
- For the coastal defences (Area 1) we have based the required height on the estimated 1 in 200 year still tide water level from the *South West Extreme Tide Level Report, 2003*. We have then included an allowance of 500mm for sea level rise and a 500mm freeboard, together with a 500mm height allowance for wave action.
- For fluvial defences at Congresbury (Area 4) we have used the 1D model with ‘glass walls’ to estimate the water level of the 1 in 100 year event. We have then added 200mm for climate change and 500mm freeboard to this water level to produce the assumed height of the defence.

To produce new defences an appropriate study would be required to determine the most appropriate line of the defence along with the defence type and crest. Once these factors are determined then approximate costs could be estimated more accurately.

With new defences there is also a need to determine who is responsible for the maintenance of the structure. This is something that would need to be determined by North Somerset Council, but may also be dependent on who benefits from the defence. For example, if the defence solely benefits a new development then we would suggest that the developer should pay for the construction and maintenance of the defences for a specified duration, although it may be more appropriate for the Council or Environment Agency to be responsible for actually undertaking the maintenance work. Where existing properties, along with new properties, will benefit from the defence, then the cost of maintenance could be shared between the developer and the Council / Environment Agency. Once again it may be most appropriate for Council or Environment Agency to be responsible for undertaking the maintenance.

It should be noted that PPS25 strongly recommends that new buildings should only be built in flood risk areas as a last resort. Before any new development proceeds the sequential test must first therefore be undertaken.

Table B1 below shows the findings of this assessment, including details of the existing defences and the approximate costs for increasing these defences.

Table B1 – Summary of findings of raising standard of protection assessment

Location	Type	SOP (yrs)*	Current height (mOD)	200 WL (mOD)	Total additional height required (m)***	Length (m)	Construction material	Cost to raise level (£)**	Additional comments
Area 1 - Coastal strip from south of Clevedon to Ham Green									
Portbury Wharf (embankment between Royal Portbury Dock and Portishead Marina)	Sea defence, reveted raised earth embankment	5	8.1	9.09	1.99	1568	Clay fill raising	£2,000,000	Raise crest level and widen on rear face to maintain crest width. Assume 4m crest width and 1 in 3 slope
Royal Portbury Dock (western side of docks adjoining 'Portbury Wharf')	Sea defence, raised earth embankment	100	9.6	9.09	1.5	396	Clay fill raising	£350,000	Raise crest level and widen on rear face to maintain crest width. Assume 4m crest width and 1 in 3 slope. Raised 0.5m for wave action.
Portbury Wharf / Portishead Marina (western end of Portbury Wharf and along Portishead Marina)	Sea defence, hard defence: sea wall	100	8.6 - 12	9.09	1.49	1388	New RC wave wall (retired from seawall)	£1,400,000	-
Woodhill Bay, Portishead (esplanade adjacent to Battery Point)	Sea defence, hard defence: sea wall	50	8.0	9.09	2.09	108	New RC wave wall (retired from seawall)	£350,000	-

Area 1 - Coastal strip from south of Clevedon to Ham Green									
Location	**Type**	**SOP (yrs)***	**Current height (mOD)**	**200 WL (mOD)**	**Total additional height required (m)*****	**Length (m)**	**Construction material**	**Cost to raise level (£)****	**Additional comments**
Woodhill Bay, Portishead (esplanade between low cliff to north and Beach Rd West)	Sea defence, hard defence: sea wall and revetment	50	7.3	9.09	2.79	463	New RC wave wall (retired from seawall)	£1,900,000	-
Clevedon (Elton Road)	Sea defence, hard defence: sea wall	50	8.8	8.66	1.5	184	New RC wave wall (retired from seawall)	£600,000	Raised 0.5m for wave action.
Clevedon (Marine Lake)	Sea defence, hard defence: sea wall	100	9.1	8.66	1.5	281	New RC wave wall (retired from Marine Lake)	£900,000	Raised 0.5m for wave action.
Clevedon (Marine Lake)	Sea defence, hard defence: sea wall	50	8.3	8.66	1.36	49	New RC wave wall (retired from Marine Lake)	£200,000	-

* SOP as stated in NFCDD

** Costs rounded up to nearest £100,000

***Total additional height required includes freeboard allowance

Area 4 – Land around Yatton / Congresbury									
Location	**Type**	**SOP (yrs)***	**Current height (mOD)**	**200 WL (mOD)**	**Total additional height required (m)*****	**Length (m)**	**Construction material**	**Cost to raise level (£)****	**Additional comments**
Confluence of tributary with main river, upstream of Congresbury Bridge to Moor Bridge	Right bank, raised earth embankment	50	7.65- 8.5	9.7	2.7	685	Clay fill raising	£600,000	-
Parallel with Mill Lane/Mill Leg junction in Congresbury to Moor Bridge	Left bank, raised earth embankment	100	8 – 8.6	9.7	2.2	1100	Clay fill raising	£700,000	-

* SOP as stated in NFCDD

** Costs rounded up to nearest £100,000

***Total additional height required includes freeboard allowance