ROYAL HASKONING

Weston-super-Mare Flood Management Study
Phase II
Options Report

June 2007
Final Report
9S0176

North Somerset Council

South West of England Regional Development Agency

Environment Agency

English Partnerships
The National Regeneration Agency

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ROYAL HASKONING

HASKONING UK LTD.
COASTAL & RIVERS

Elizabeth House
Emperor Way
Exeter, Devon EX1 3QS
United Kingdom
+44 (0)1392 447999 Telephone
01392 446148 Fax
info@exeter.royalhaskoning.com E-mail
www.royalhaskoning.com Internet

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Drafted by	Mercedes Uden	
Checked by	Ian Haken	
Date/initials check	……	……
Approved by	Hamish Hall	
Date/initials approval	……	……

This Options Report has been prepared for internal use by the Weston Vision Partnership for the purpose of supporting recommendations for further studies and strategic decision making. This report is not intended to be exhaustive.

Please note that no guarantees can be given at this stage that a scheme will ultimately be undertaken by any party.

This report represents the views of Royal Haskoning, which have been guided and endorsed by a steering group comprising representatives from North Somerset Council planners and engineers, the Environment Agency and West Mendip Internal Drainage Board (IDB). All parties have supplied data and attended progress meetings.

SUMMARY

The Weston-super-Mare Flood Management Study investigates flooding between the River Banwell, Moorland Drove Rhyne, West Wick Rhyne and Way Wick Rhyne in the north of Weston-super-Mare and the Uphill Great Rhyne and Cross Rhyne in the south.

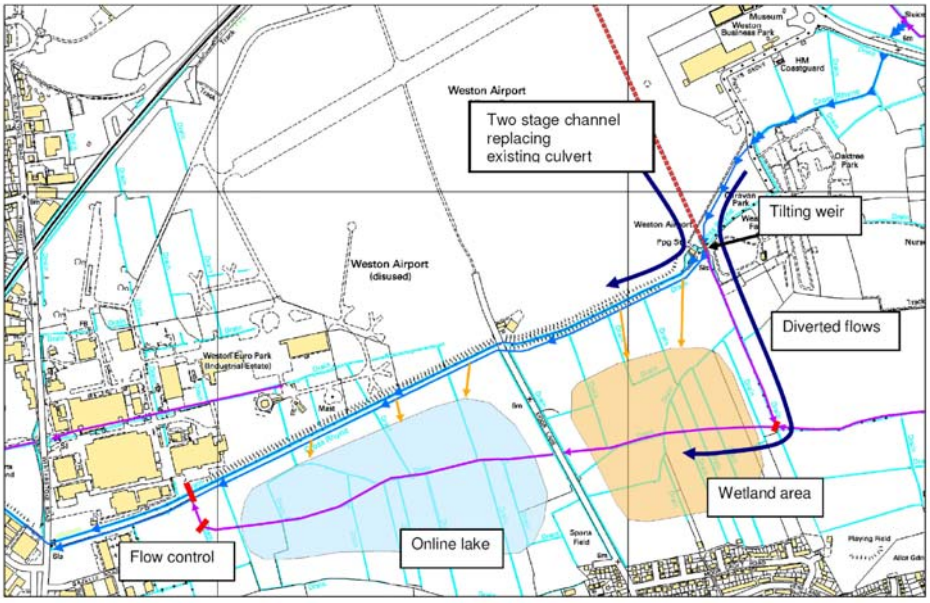
This study aims to develop a strategy for delivering a comprehensive flood management scheme in Weston to protect both existing property and to assess and facilitate development in the Weston Vision area. Pre-feasibility reports formed the initial stage (Phase I) of this study with focus on the Uphill Great Rhyne and Cross Rhyne catchment and a separate report focusing on the River Banwell catchment. This report is a high level flood risk assessment for the Weston Development Area and whilst it contains elements that are found within a Strategic Flood Risk Assessment (SFRA) it does not replace the SFRA for North Somerset Council which is district wide.

An outline assessment of historical, current and future flooding events due to increased development has been made including the identification of flood extents and the numbers of properties at risk. The effect of increased urbanisation was applied to the hydrology of the two catchments to identify changes to peak run off volumes which were incorporated into an extended hydraulic model following on site topographic survey work.

Twenty four options to reduce flooding and flood risk to existing properties, and allow development were examined through the development and assessment of detailed hydraulic modelling to identify a preferred option in terms of flood risk mitigation. These options were then assessed in terms of environmental, human environment and economic impacts to identify preferred overall solution to comply with the aspirations of the Partnership and the Weston Vision.

The preferred options have been developed to assess their effectiveness and information regarding costs, properties at risk and changes to flood extents has been provided. The preferred options are given below.

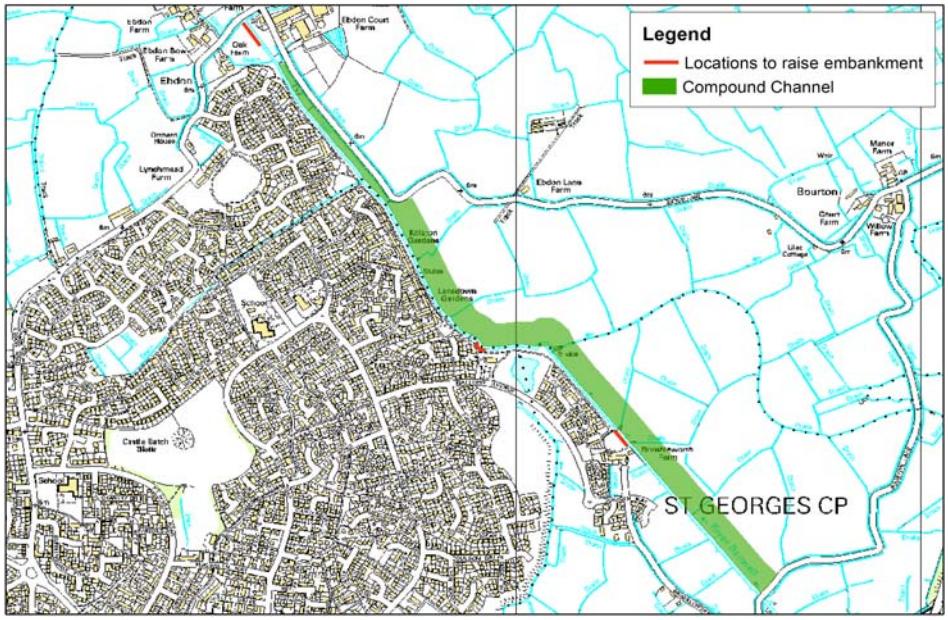
Uphill Great Rhyne: Option 10 - Diverted Cross Rhyne with online lake and wetland areas and culvert works



Flows from Cross Rhyne would be diverted along a new channel starting at the old airfield pumping station and running through an area of wetland and then into a lake providing online storage and recreational facilities. The lake would also be fed from the freshwater stream which flows into Hutton and Locking Rhyne to help to maintain water quality. Flow leaving the lake would be throttled at the downstream end near to Winterstoke Road. Flow from the airfield and former airfield culvert (which would be opened up and replaced with a two stage channel) would drain into the existing Cross Rhyne and Hutton Moor Rhynes running south of the airfield.

The cost of this option has been calculated at £4,900,000 and includes site investigation, set-up and prelims, service diversions and all works including bank raising. This cost assumes that excavated material will be transported and spread on adjacent land to a depth of 500mm approx. The annual maintenance charge is expected to be £70,000. This cost does not include for land purchase and compensation costs. Should the disposal of material off site be necessary, landfill charges are expected to be in excess of £9m which is the potential worst case scenario. Economic and environmental savings may be made through the more sustainable use of excavated material elsewhere.

River Banwell: Option 11 - Compound Channel



A compound channel would be constructed downstream of the M5 motorway with a lowered bank extending laterally for 50m on the right bank of the channel over a 1900m stretch of channel. This will provide additional storage and lower water levels locally at times of high flow with minimal disruption to the existing agricultural land use (grazing). At certain points along the left bank of this channel the defence is known to have low points which would require a small increase in elevation.

The cost of this option has been calculated at £900,000 and includes site investigation, set-up and prelims, service diversions and all works including bank raising. This cost assumes that excavated material will be transported and spread on adjacent land to a depth of 500mm approx. The annual maintenance charge is expected to be £4,000. This cost does not include for land purchase and compensation costs. Optimism bias is not included in the figure above and if assumed to be at 60% will raise the total cost to

£1,440,000. Should the disposal of material off site be necessary, landfill charges are expected to be in excess of £1.9m which is the potential worst case scenario. Economic and environmental savings may be made through the more sustainable use of excavated material elsewhere.

Whilst a mechanism for contributions has yet to be finalised by North Somerset Council (NSC) we have provided a suggested methodology as to how this could work.

A number of developer conditions have been provided covering generic aspects across the development area as a whole and specific to the five key development sites within the Weston Development Area. These conditions have been supplied by the West Mendip Internal Drainage Board, North Somerset Council, the Environment Agency and the requirements of Planning Policy Statement 25 (PPS25) which seeks to avoid, mitigate and manage flood risk.

The information in this report (particularly in Appendix G) will help to guide the local planning authority in making judgements on allocating land for potential development through the planning process. It also informs the preparation of strategic policy and development control policies towards flooding and flood risk which can then be included in the Local Development Framework. The information may also be used as evidence for informing planning policy and development control decisions. It should be noted that this report does not remove the requirement for site specific Flood Risk Assessments.

A programme of environmental studies to inform an environmental baseline for use in Environmental Impact Assessments and to inform the options above has also been carried out. This includes a river corridor survey, an extended Phase 1 Habitat Survey and water quality sampling work.

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1 BACKGROUND

1.1 Weston Flood Management Study

1.1.1 Royal Haskoning were retained by a Partnership comprising North Somerset Council, the Environment Agency, South West of England Regional Development Agency and English Partnerships to undertake the Weston Flood Management Study.

1.1.2 The Weston Flood Management Study aims to develop a strategy for delivering a comprehensive fluvial flood defence scheme in Weston to protect both existing property and to assess and facilitate future development in the Weston Vision area.

1.1.3 Two main catchments at risk of flooding have been identified within the Weston Vision area, these are the River Banwell and the Uphill Great Rhyne. Two pre-feasibility reports were delivered as part of the initial stage (Phase I) of the Weston Flood Management Study, focusing on the above catchments. These pre-feasibility reports form the basis for more detailed investigations to be carried out, under the Weston Flood Management Study Phase II, into flooding mechanisms, potential flood extents and sustainable flood management options.

1.2 Location and supporting information

1.2.1 The locations of the two catchments within Weston-super-Mare are outlined on the map in figure 1.1. This report forms part of the Weston Flood Management Study which aims to investigate flooding between the Uphill Great Rhyne system in the south west and the River Banwell in the north east. The sub-catchments within the two areas are defined by the shaded and numbered areas on figure 1.1.

1.2.2 The Uphill Great Rhyne and Cross Rhyne system is approximately 9km in length and drains water from the area of Weston airfield. Uphill Great Rhyne runs from Wyvern School through the residential areas of southern Weston-super-Mare and Uphill to a discharge at Uphill Sluice. A 1.6km culvert feeds surface water into the head of Uphill Great Rhyne. A second major channel, Cross Rhyne, joins Uphill Great Rhyne upstream of the hospital site. Cross Rhyne drains water from the Weston Airfield area. The channel outfalls into Uphill Pill, via Uphill Sluice. Uphill sluice, newly constructed in 2004, is a tidal sluice which prevents tide water entering Uphill Great Rhyne at high tide and allows the Rhyne to drain at low tide. There is a period of approximately 3 hours on each tide when the Uphill Great Rhyne is tide locked and cannot drain.

1.2.3 The River Banwell, is largely an artificial channel 9km in length, and is situated to the east of Weston-super-Mare. The river rises at a spring at Banwell Village, drains the surrounding agricultural land and discharges through New Bow Sluice, a tidal defence structure. The current sluice was constructed in 1990, replacing an earlier sluice of inadequate capacity and is 0.8km upstream of the confluence with the Severn Estuary. The gradient of the river channel is very shallow (approximately 1 in 3300 or 2.7m over 9km) and the flow in the river is consequently dominated by daily tide locking at the New Bow sluice. Ground water levels are reported to be very close to ground level in some of the developed areas. This causes problems with constructing local sustainable urban drainage attenuation measures and results in the potential for problems with water logging issues.

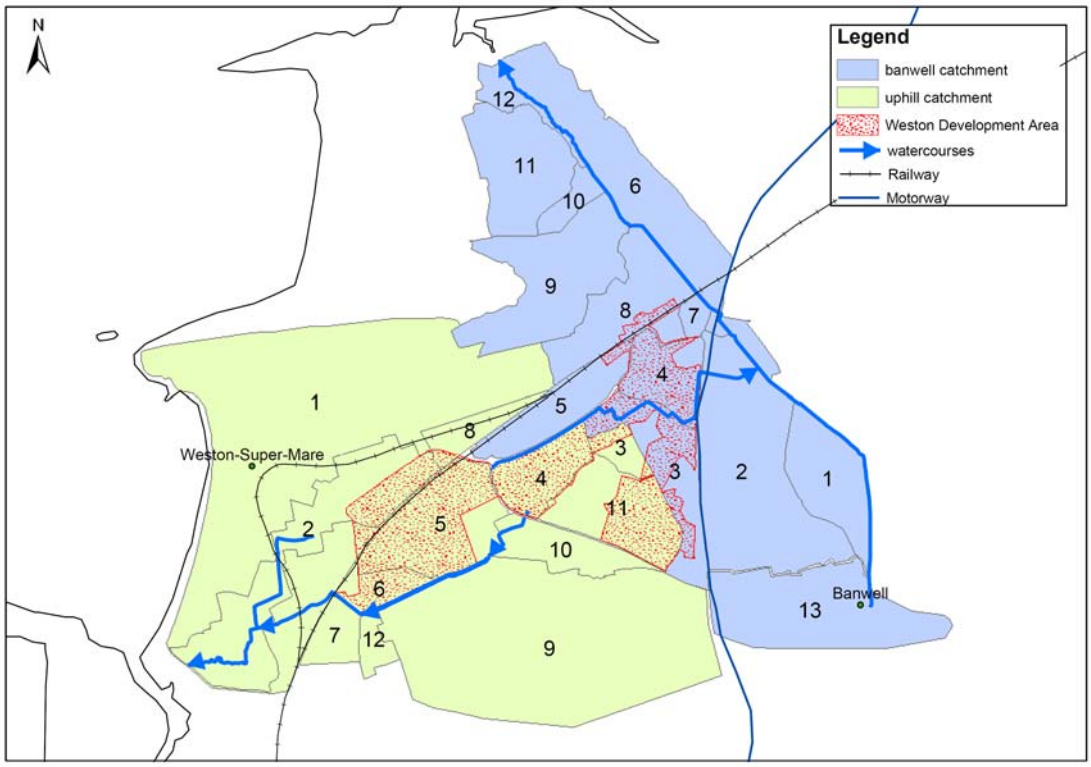
1.2.4 Due to the marked growth in development along the St Georges area of the Banwell catchment in the 1970s, it was necessary to pump surface water from these new

developments into the River Banwell and construct a number of small storage facilities to counteract the increased flood risk. Despite a number of mitigation measures being in place, their effectiveness and interrelationship under extreme events is believed to be questionable.

1.2.5 The Environment Agency undertakes regular maintenance work along the River Banwell to clear weed growth and other obstructions. However due to environmental and access issues, short stretches of river are left where no weed clearance is undertaken, resulting in sections with high channel roughness and therefore a reduced capacity. In these reaches a balance needs to be achieved to maintain a good environmental habitat whilst still maintaining a good flow though the channel.

1.2.6 West Mendip Internal Drainage Board (IDB) operate and maintain the rhyne system. This includes water control structures which are used to control water levels in the area. Typically, during the summer months, water in the river is held back or penned to provide water for irrigation, wet fencing and general amenity. During the winter months these various water level control structures are opened to allow the free discharge of flow and to reduce flooding risks. The IDB also operate control structures as part of local flood storage systems in the area of the Locking Castle development.

Figure 1.1
Catchment overview map



1.2.7 Following the publication of Planning Policy Statement 25: Development and Flood Risk (PPS25) in December 2006 and the advice and requirements of the Environment Agency and North Somerset Council, this report follows the guidance of PPS25. PPS25 replaces Planning Policy Guidance 25 (PPG25): Development and Flood Risk published in 2001.

2 FLOODING EVENTS

2.1 Historical Flooding Events

2.1.1 There is a history of fluvial and tidal flooding within the study area. The north of Weston-super-Mare is affected by flooding which results from overtopping of the sea defence wall between marine lake and Grand Pier. Work to design and build a new sea defence scheme is currently being undertaken to address these tidal flooding issues. In addition, anecdotal reports indicate that in recent years minor flooding has also occurred in the low lying areas (such as the airfield and the railway triangle).

2.1.2 The following are a number of major floods that have occurred in the last 100 years.

2.1.3 1903
In 1903 there was a significant breach of the seawall that exposed services and caused disruption.

2.1.4 1968
Flooding of the Banwell catchment occurred in 1968 following a storm over the Mendip Hills. The flooded areas included Banwell Moor to the north of Banwell Village, part of St Georges Village and an area between St Georges and West Wick. It is known that the River Banwell continued to rise for approximately six days after the storm had passed, illustrating the slow response time of the catchment. It is important to note however, that the catchment and watercourses themselves were considerably different at that time in both alignment and cross-section to the current day situation. Furthermore, St Georges had experienced very little development prior to 1968 and the M5 motorway had yet to be built.

2.1.5 1981
In 1981 the failure of the old Uphill tidal sluice during a storm led to tidal inundation and extensive flooding in Uphill village. At the same time, sea defences were also breached in Uphill. However, the inner flood banks held which prevented further flooding.

2.1.6 During this event most seafront properties were flooded and the Marine Lake Colonnade was severely damaged and subsequently demolished. The flooding to the town was exacerbated because the promenade parapet wall also failed. Although the wall was repaired, it has the potential to fail again which would result in increased flooding. Similar flooding was observed in 1990.

2.1.7 Winter 1990-1
Tidal flooding to sea front and damage to existing defences.

2.1.8 October 1996
Coastal flooding occurred in October 1996 affecting an area of approximately 2 hectares containing approximately 50 properties and caused flooding to many roads.

2.1.9 January 2002
More recently, flooding occurred in January 2002 after heavy rain fell across the whole catchment. In this instance the flooded area was Banwell Moor between East Moor Rhyne and Middle Moor Rhyne and the low lying areas of Weston Airfield. Although it is believed that no properties were flooded, flood water reached areas close to Moor Dairy and Moorlands Farm.

2.2 Existing Situation

2.2.1 A floodplain is an area that would naturally be affected by flooding if a river rises above its banks, or where high tides and stormy seas cause flooding in coastal areas. Over hundreds of years, natural floodplains have been built on and today many towns and cities exist on floodplains. Some settlements and areas of agricultural land have flood defences in place to reduce the risk of flooding. It should be noted however that in these areas there will always be some risk (however low) of flooding.

Environment Agency Flood Zones

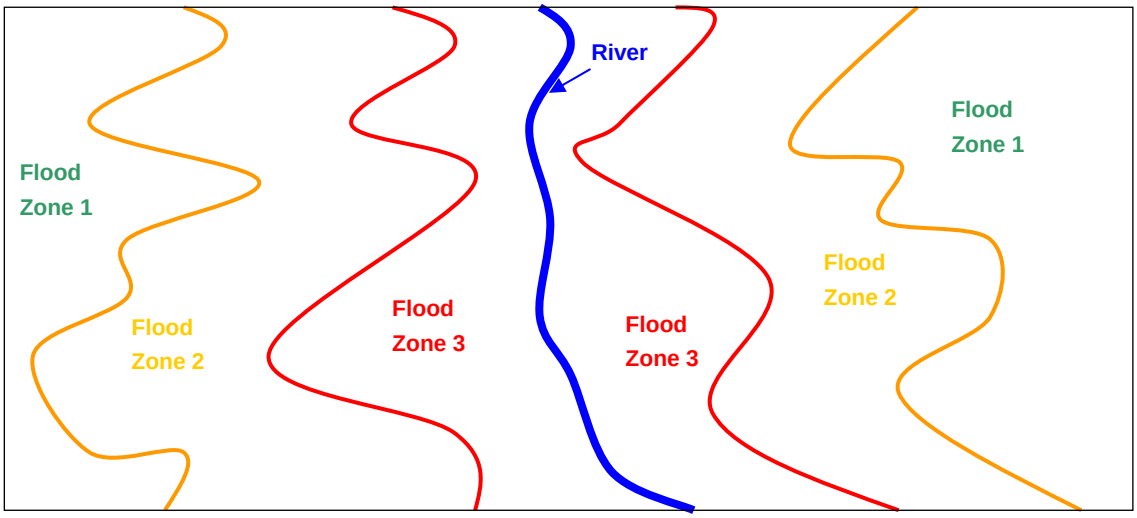
2.2.2 The Environment Agency produce a Flood Map (which is updated quarterly) depicting areas where there is a high risk (Flood Zone 3) or a low-to-medium risk (Flood Zone 2) of fluvial or tidal flooding. These zones do not take into account any flood defences that could reduce the impact of flooding if there was a flood event, because the defences can be breached, or overtopped and may not be in existence for the lifetime of any development. The flood zones cover the watercourses in the study area which have a catchment area of greater than 3km2 and indicate where flooding can occur at postcode level. This Flood Map can be viewed on the Environment Agency website at www.environment-agency.gov.uk. The Environment Agency Flood Map does not include for ground water or surface water flooding.

2.2.3 The Flood Map is split into three areas (as indicated in figure 2.1):
Environment Agency Flood Zone 3 is the area that could be affected by fluvial or tidal flooding if there were no flood defences. The probability of tidal flooding in this area is at or greater than 0.5% (1 in 200 years) and the probability of fluvial flooding is at or greater than 1% (1 in 100 years). This is described as a high risk area.

2.2.4 Environment Agency Flood Zone 2 shows the additional extent of an extreme fluvial or tidal flood with no defences in place. These areas are likely to be affected by a major flood with up to a 0.1% (1 in 1000) chance of occurring each year. This is described as a low to medium risk area.

2.2.5 All land not in Environment Agency Flood Zones 2 or 3 are in Flood Zone 1 which has little to no risk of flooding and the probability of flooding is less than 0.1%.
(See www.environment-agency.gov.uk for more detail)

Figure 2.1
Environment Agency Flood Zone Location in relation to a watercourse



2.2.6 Hydrodynamic models have been developed as part of this study for both catchment areas. The peak levels from the hydraulic model were used in conjunction with LiDAR Digital Terrain Model (DTM) data to create fluvial flood extent outlines for the 1 in 100 year return period. Due to the differences in modelling technique, discrepancies between the Flood Zone 3 and modelled extent outlines (with the inclusion of defences) are to be expected. The Environment Agency will be providing guidance to ensure that the correct outlines are adopted following this study.

2.2.7 Following the output from a number of studies such as the North Wessex Tidal Flood Zone Compliance and Areas Benefiting from Defences (ABDs) Main Stage (Royal Haskoning, ongoing) new tidal extents will be adopted by the Environment Agency across the Weston-super-Mare area. For the purposes of this study, the current tidal flood zone extents as published by the Environment Agency were used.

Uphill Great Rhyne and Cross Rhyne Catchment

2.2.8 The very low hydraulic gradient and presence of tide locking with the Uphill Great Rhyne and Cross Rhyne catchments means the watercourses have insufficient capacity to drain the catchment effectively during heavy rainfall. The condition of the culverts within the study area is unknown but they are believed to be in excess of 30 years old. A CCTV survey of the 2.6km covered by the two main culverts (across the airfield and from Kenn Close to Milton) has been recommended to the Weston Vision Partnership in order to fully assess their condition.

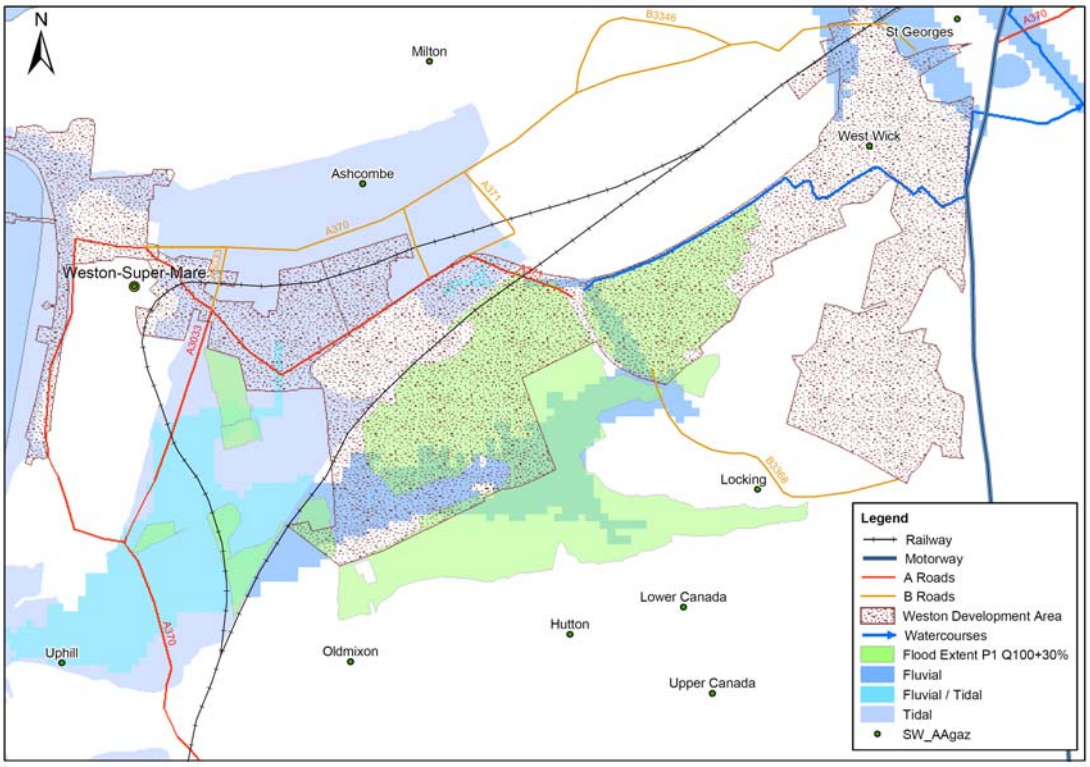
2.2.9 The replacement of the sluice at Uphill in 2004 and further sea defences provide a 1 in 200 year standard of protection against tidal flooding for the Uphill area. Other areas of the catchment have an indicative standard of protection against fluvial flooding of between 1 in 50 and 1 in 200 years dependent on land use and the existing density of development.

2.2.10 Following guidance from the Environment Agency, West Mendip Internal Drainage Board and PPS25, a 20% increase in peak rainfall intensity and fluvial flows is considered appropriate to take account of the effects of climate change until 2085. This increase in flows has been taken into account with the creation of potential flood extents and must be accommodated within the design of any flood defence structures. An additional 10% increase in flows has also been included as a precautionary approach and to provide allowance for the uncertainties of modelling a rhyne system.

2.2.11 Figure 2.2 shows the current fluvial Flood Zone 3 (1% probability) extents for the Uphill Great Rhyne Catchment and the extents of the 100 year return period flows plus 30% as derived from the hydraulic modelling for this study. More detail of the flood extents is provided in drawing AA_0104 in Appendix A. It is envisaged that the detailed modelling and extents derived from this study will be adopted by the Environment Agency as their definitive Flood Zone 3.

2.2.12 For Cross Rhyne, flooding is shown to be more extensive than previously indicated by Flood Zone 3, as indicated by the modelled extents. The Flood Zone 3 data are predominantly from the Institute of Hydrology generalised data and therefore is identified as low in confidence. Fluvial flooding extents from the Uphill Great Rhyne are reduced on the upstream reach and for the downstream reach no extents have been identified.

Figure 2.2
Uphill catchment: Current Flood Zone 3 extents and
Q100 + 30% pre-development (P1) extents (without mitigation)



Banwell Catchment

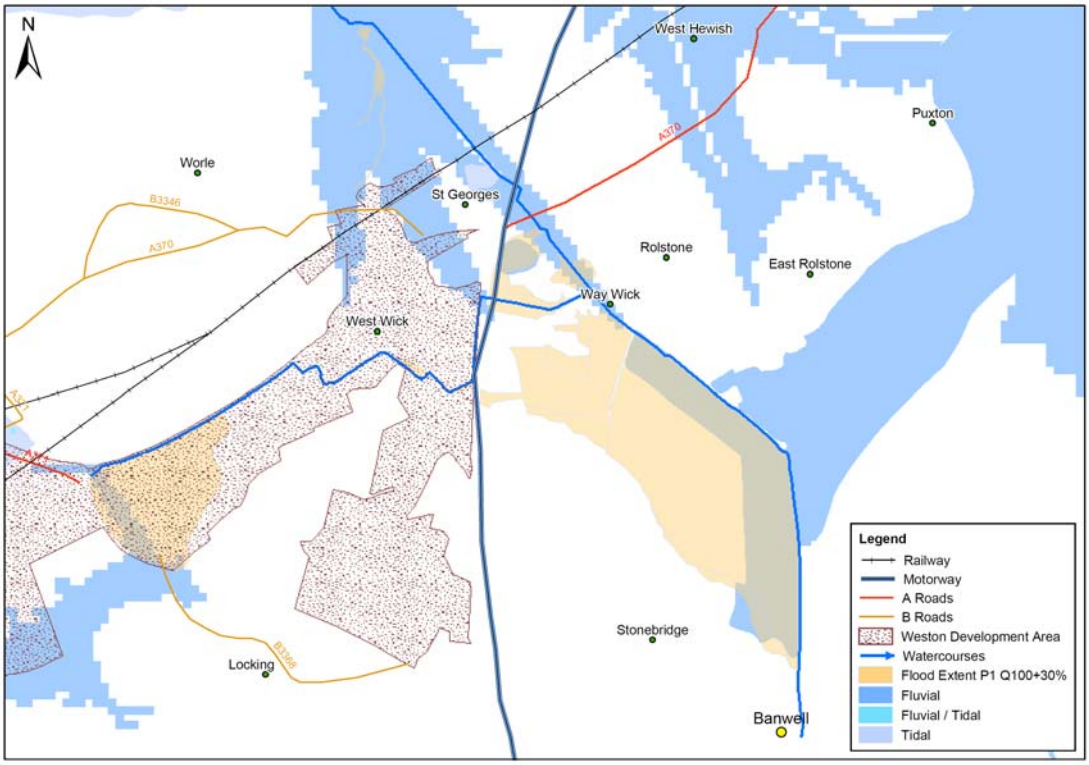
2.2.13 The developed areas of the Banwell catchment (such as St.Georges) have a far quicker response time to rainfall than the low lying agricultural areas, with the majority of these quick response flows being discharged to the middle reaches of the river. Due to the low hydraulic gradient, this can lead to reverse flows along the river caused by a local raising of water levels near the urban reaches, which can lead to flooding upstream.

2.2.14 The indicative standard of protection for fluvial defences within the River Banwell catchment is between 1 in 50 and 1 in 200 years dependent on land use and the existing intensity of development.

2.2.15 Figure 2.3 show the current Flood Zone 3 (1% probability) extents for the Banwell Catchment and the extents of the 100 year return period flows plus 30% as derived from the hydraulic modelling for this study. More detail of the flood extents is provided in drawing AA_0102 in Appendix A.

2.2.16 The model has been designed to be run at the 100 year return period level and therefore cannot accommodate the 1000 year flows without significant adjustment. Therefore the current Flood Zone 2 extents (0.1% probability) are the best indication of flood risk due to extreme events.

Figure 2.3
Banwell catchment: Current Flood Zone 3 extents and
Q100 + 30% pre-development (P1) extents (without mitigation)



2.2.17 For Banwell Moor, flooding is shown to be more extensive than previously anticipated by Flood Zone 3, as shown by the modelling and historical accounts of the extent of flooding. Land east of the River Banwell falls within the Congesbury Yeo catchment and is therefore outside of the scope of this study. Extensive flooding is indicated in the West Wick and Worle area from Flood Zone 3. However following existing development and associated site works and raised ground levels, this study indicates that flooding has been greatly reduced within this area.

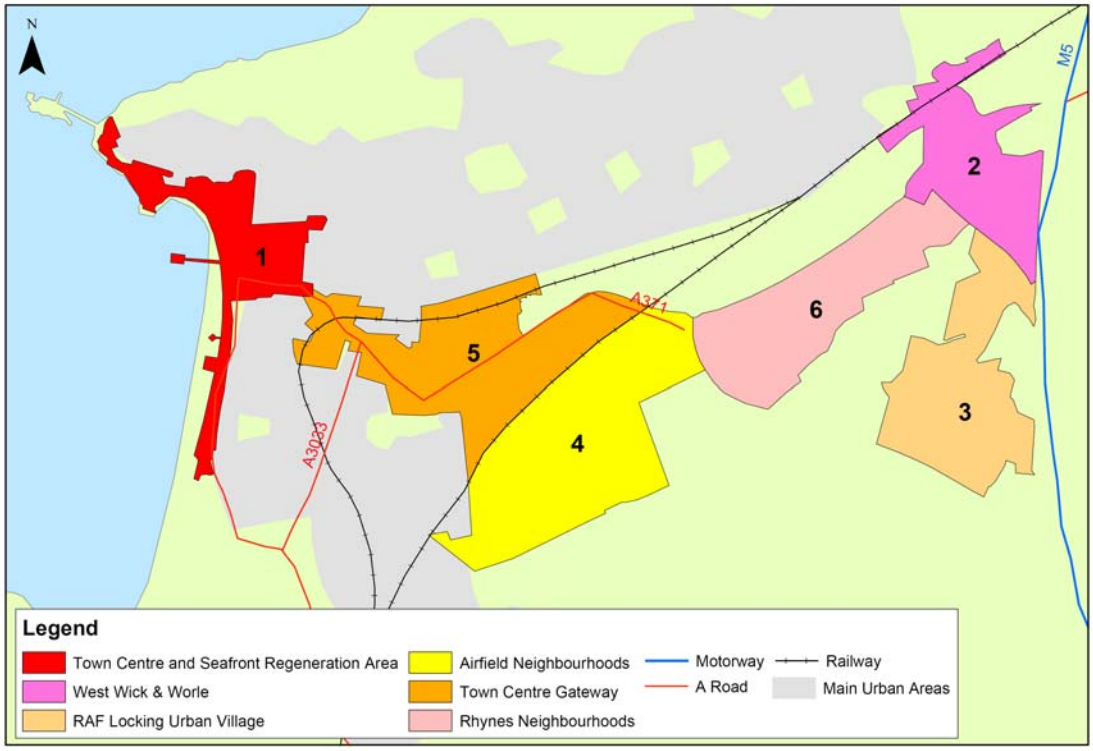
2.3 Future Development

2.3.1 The Weston Area Development Framework (June 2005) sets out a vision for regeneration within Weston-super-Mare. Development of a number of sites within the Weston Regeneration Area is key to this framework with residential and commercial development planned within both catchments. Some 9,400 new dwellings are expected in Weston-super-Mare by 2021 (although this could be as many as 16,000), with approximately 340 hectares of land to be developed as mixed use residential land. An additional 250 hectares of previously developed land will also be brought into use. Figure 2.4 shows the extent of key development areas within this area as outlined in the Weston Area Development Framework, with more detail provided in drawing AA_0200 in Appendix A.

2.3.2 For the Banwell catchment, both commercial and residential development is planned in the RAF Locking area, whereas development in the West Wick, Worle and St Georges area will be predominantly residential. Within Uphill Great Rhyne catchment, both

commercial and residential development is planned in the RAF Locking area (which falls within both catchments) and the Airfield Neighbourhoods. An extensive seafront regeneration programme is also linked to the Weston Sea Defences project.

Figure 2.4
Weston Development Area: key areas



2.3.3 Government guidance, Planning Policy Statement: Development and Flood Risk 25 exists to assist planning officers making decisions about land allocation in terms of flood risk. Any new development within the catchment will require a flood risk assessment as defined by PPS25. The flood risk assessment will have to demonstrate that the development does not put people or assets connected with the development at risk of flooding. It also has to demonstrate that, as a result of development, flood risk is not increased anywhere else in the catchment.

2.3.4 Whilst this study does not eliminate the requirement for a developer to produce a flood risk assessment, it does investigate flood management options that are strategically planned to improve the current situation and facilitate future development in a coherent and coordinated manner. As well as reducing flood risk, the variety of options examined seeks to meet greater objectives such as enhancing the environment and ensuring long term sustainability. This may take the form of habitat creation and or the creation of amenity open space.

2.3.5 A summary of each of the development areas is given in table 2.1 indicating the potential land allocations, flood risk and broad scale assessment under the PPS25 guidelines. When allocating sites for development PPS25 states that this should be done in descending order of flood risk (the sequential test). The order of preference for development of key areas within the Weston Development Area is also given in table 2.1 based on their location in relation to the flood extents for Q100 + 30% pre-development flows as indicated by their ranking.

Table 2.1: Summary of Development Areas

Rank	Area	Land Allocations	Main Flood Risk	PPS25 guidelines: flood zone definition and comments (see Appendix G for more PPS25 information)
1	**RAF Locking** (Banwell and Cross Rhyne catchments)	Mixture of employment and residential development as well as open spaces. Mainly previously developed land.	Surface water flooding through increased runoff	Zone 2: suitable for most types of development. Seek opportunities to reduce overall level of flood risk and apply appropriate SUDs* techniques to deal with increased surface water runoff.
2	**West Wick and Worle** (Banwell catchment)	Mixture of employment and residential development as well as open spaces. Previously developed land.	Surface water flooding through increased runoff	Zone 2: suitable for most types of development. Seek opportunities to reduce overall level of flood risk and apply appropriate SUDs* techniques to deal with increased surface water runoff.
3	**Town Centre Gateway** (Cross Rhyne catchment) *southern area only addressed within this study	Mixed use, retail and leisure development. Existing developed land.	Tidal flooding	Zone 3a: Suitable for residential development with defences. Seek opportunities to reduce overall level of flood risk and apply appropriate SUDs* techniques, relocate development to zones with lower flood risk and create space for flooding.
4	**Town Centre and Seafront** (Cross Rhyne catchment) *not addressed within this study	Redevelopment of key sites and landmark buildings. 'Civic Pride' initiative. Existing developed land.	Tidal flooding	Zone 3a: Suitable for residential development with defences. Seek opportunities to reduce overall level of flood risk and apply appropriate SUDs* techniques, relocate development to zones with lower flood risk and create space for flooding.
5	**Airfield Neighbour-hood** (Cross Rhyne catchment)	Mixture of residential, employment and leisure use developments. Previously mainly	Fluvial and surface water flooding through increased run off	Zone 3a&3b: as 3a and generally suitable for water-compatible uses and essential infrastructure. Mitigation measures will need to be taken to ensure that water flows are not impeded and flood risk is not increased elsewhere to allow development to proceed. Seek

		undeveloped land.		opportunities to reduce overall level of flood risk and apply appropriate SUDs* techniques, relocate development to zones with lower flood risk and create space for flooding.
6	**Rhynes Neighbour-hood** (Cross Rhyne catchment)	Mainly residential mixed use with some strategic open spaces. Much of this development will take place on previously undeveloped land.	Fluvial and surface water flooding through increased run off	Zone 3a&3b: as 3a and generally suitable for water-compatible uses and essential infrastructure. Mitigation measures will need to be taken to ensure that water flows are not impeded and flood risk is not increased elsewhere to allow development to proceed. Seek opportunities to reduce overall level of flood risk and apply appropriate SUDs* techniques, relocate development to zones with lower flood risk and create space for flooding.

*Sustainable Drainage Systems (SUDs)

Flood Zones definitions as in PPS25

Zone 1 Low Probability:
This zone comprises land assessed as having a less than 1 in 1000 annual probability of fluvial or tidal flooding in any year (<0.1%).

Zone 2 Medium Probability:
This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of fluvial flooding (1% – 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of tidal flooding (0.5% – 0.1%) in any year.

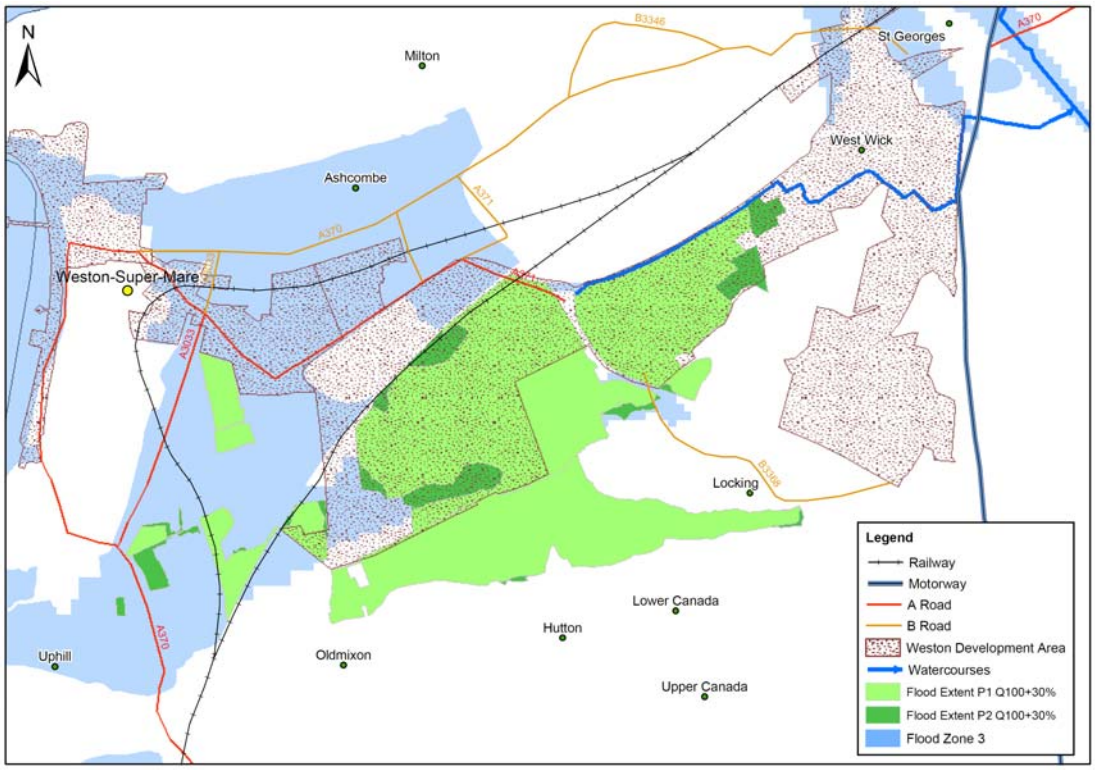
Zone 3a High Probability:
This zone comprises land assessed as having a 1 in 100 or greater annual probability of fluvial flooding (>1%) or a 1 in 200 or greater annual probability of tidal flooding (>0.5%) in any year.

Zone 3b The Functional Floodplain:
This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).

2.3.6 A more marked difference can be seen between flood extents following the development of the Uphill Great Rhyne catchment. Figure 2.5 show the current Flood Zone 3 (1% probability) extents for the Uphill Great Rhyne catchment and the extents of the 100 year return period flows plus 30% for pre and post development as derived from the hydraulic modelling for this study. More detail of the flood extents is provided in drawing AA_0101 in Appendix A.

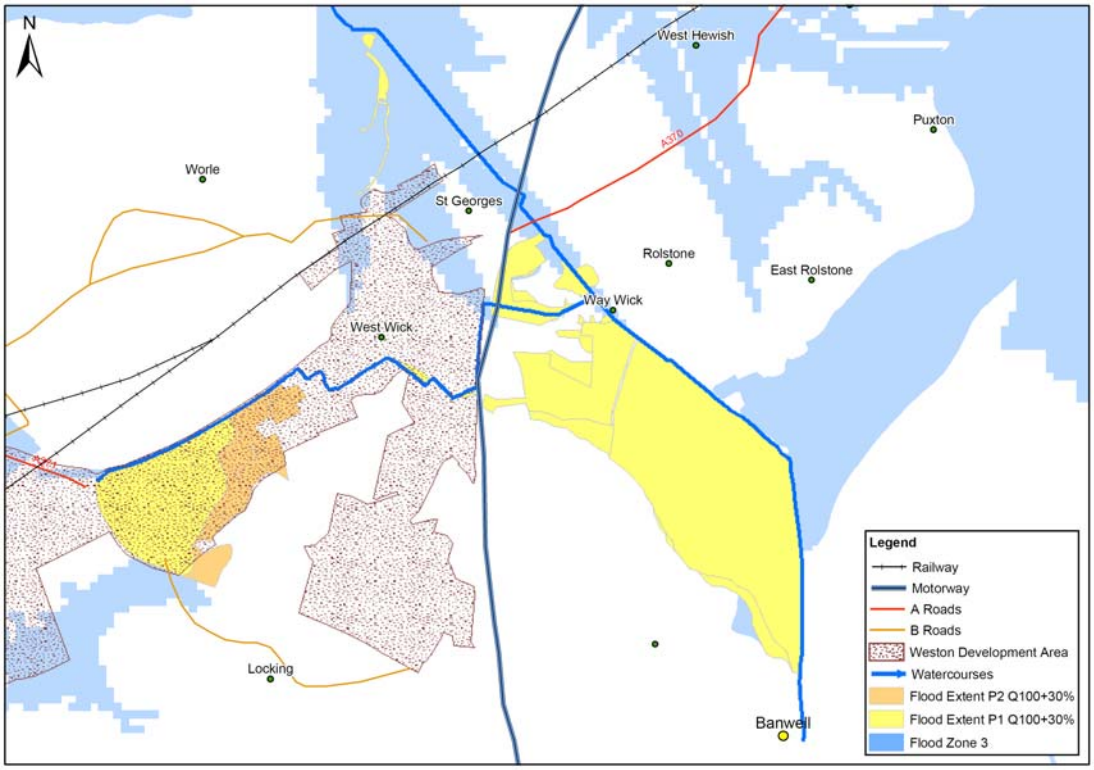
2.3.7 Sensitivity testing of the Flood Zones produced by the Environment Agency, using the 20 per cent from 2025 to 2115 allowance for peak flows, suggests that changes in the extent of inundation are negligible in well-defined floodplains, but can be dramatic in very flat areas. However, changes in the depth of flooding under the same allowance will reduce the return period of a given flood. This means that a site currently located within a lower risk zone could in future be re-classified as lying within a higher risk zone. This in turn could have implications for the type of development that is appropriate according to its vulnerability to flooding. It will therefore be important that developers, their advisors and local authorities refer to the current Flood Zones and the Strategic Flood Risk Assessment when preparing and considering proposals.

Figure 2.5
Uphill catchment: Current Flood Zone 3 extents, Q100 + 30% pre-development (P1) and Q100 + 30% post-development (P2) extents (without mitigation)



2.3.8 Within the Banwell catchment there is not a significant increase in flood extents between pre and post development. Figure 2.6 shows the current Flood Zone 3 (1% probability) extents for the Banwell catchment compared with the extents of the 100 year return period flows plus 30% for pre and post development derived from the hydraulic modelling. More detail of the flood extents is provided in drawing AA_0103 in Appendix A.

Figure 2.6
Banwell catchment: Current Flood Zone 3 extents, Q100 + 30% pre-development (P1) and Q100 + 30% post-development (P2) extents (without mitigation)



2.4 Properties at risk

2.4.1 A comparison has been made between the numbers of properties at risk for the current Flood Zone 3 extents and the Q100 + 30% extents for both pre and post development (without mitigation) scenarios in table 2.2 below. This table clearly indicates the cautious approach adopted by the previous Flood Zone 3 extents, which are defined as an area which is considerably beyond the limits of the modelled flood extents produced as part of this study.

2.4.2 Sections 3.4 and 3.6 detail how the additional flows and therefore associated extents were calculated with respect to increased development across both catchments.

Table 2.2
Properties at risk pre and post development (without mitigation)

Location	Fluvial Flood Zone 3	RH modelled extents	
		Pre-development	Post-development
Banwell catchment	1833	14	14
Uphill catchment	2699	84	188

3 OPTIONS OVERVIEW

3.1 Outline of all options considered

3.1.1 The following scheme options were considered for each catchment, aiming to provide flood management for the catchment which would protect both existing properties and future development sites as well as considering the potential for future development. Details of capital options are shown on the drawing numbers indicated in table 3.1 and can be found in Appendix B.

Table 3.1
Options Drawings

Catchment	Option/s	Drawing Number
Uphill Great Rhyne and Cross Rhyne	4 & 5a	AA_0351
	5b & 9	AA_0352
	6 & 7	AA_0353
	10	AA_0354
Banwell	4 & 9	AA_0301
	5a, 5b, 6a, 6b & 8	AA_0302
	7 & 11	AA_0303

Uphill Great Rhyne and Cross Rhyne

Option 1 – Do Nothing
Option 2 – Do Minimum/Existing
Option 3 – Flood Warning
Option 4 – Flood Banks / Walls
Option 5a – Flood Storage (via channel amalgamation)
Option 5b – Flood Storage (as in 5a) plus recreation lake and wetland area
Option 6 – Culvert Works and Flood Storage (as in 5a)
Option 7 – Pumping Station, Culvert Works and Flood Storage (as in 5a)
Option 8 – Sustainable Drainage Systems (SUDs)
Option 9 – Flood Storage (as in 5b) and Flood Banks / Walls (as in 4)
Option 10 – Diverted Cross Rhyne with online lake, wetland area and culvert works

River Banwell, Moorland Drove, West Wick and Way Wick Rhyne

Option 1 – Do Nothing
Option 2 – Do Minimum/Existing
Option 3 – Flood Warning
Option 4 – Flood Banks / Walls
Option 5a – Flood Storage (Banwell Moor)
Option 5b – Flood Storage (Banwell Moor) (as in 5a) and Flood Banks / Walls (as in 4)
Option 6a – Flood Storage (Banwell Moor & New Bow) (as in 5a)
Option 6b – Flood Storage (Banwell Moor & New Bow) and Flood Banks / Walls (as in 5b)
Option 7 – Channel Widening
Option 8 – Pumping Station, Flood Storage (as in 6a) and Flood Banks / Walls (as in 4)
Option 9 – Diversion Channel
Option 10 – Sustainable Drainage Systems (SUDs)
Option 11 – Compound Channel

3.2 Uphill Great Rhyne and Cross Rhyne

3.2.1 Option 1 - Do Nothing

This option considers the cessation of all flood defence activities in the study area as a baseline for comparison of other options. This is the baseline required by Defra so that schemes in different parts of the country can be compared and prioritised. It is also good economic assessment practice.

Under this option, Uphill sluice would not be operated and all maintenance along the channel would cease. Operation of structures and maintenance carried out by the West Mendip Internal Drainage Board, including work to the structures in the adjoining rhyme system would also stop.

3.2.2 Option 2 - Do Minimum/Existing

Under this option, Uphill Great Rhyne, Cross Rhyne and nearby watercourses would be maintained by the Environment Agency and West Mendip Internal Drainage Board (WMIDB) as they are at present. Water control structures (such as Uphill Sluice) and smaller penning structures would continue to be operated to manage water levels and control flooding.

Existing flood defence structures (Uphill Sluice) would be repaired or replaced at the end of their useful life. It is assumed that work will be carried out every 25 years at Uphill Sluice to replace mechanical and electrical systems and telemetry components.

3.2.3 Option 3 - Flood Warning

This option would require the installation of a flood warning gauging station on the Uphill Great Rhyne or Cross Rhyne. The gauge would then be used by the Environment Agency to assess when flood warnings are necessary and to enable them to issue warnings. It should be noted that these warnings would apply only to fluvial flooding as tidal flooding would be caused by a failure of the sluice which would not be possible to predict with sufficient lead time. This option will not increase the standard of protection for properties in the flood plain but could potentially reduce flood damages.

As the catchment is draining through a rhyne system over a short distance, it is thought that a maximum lead time of only 1 hour could be achieved.
Tidal flood warnings are already issued for Weston-super-Mare by the Environment Agency.

3.2.4 Option 4 - Flood Banks / Walls

Flood banks or walls would be built along parts of Uphill Great Rhyne and Cross Rhyne to increase the channel capacity and provide increased protection to properties. Through built up areas flood walls would be constructed (approximately 2.8km), with earth embankments forming the defence through open areas (approximately 3km). Where possible the earth embankments would be set back as far as possible so as not to restrict functional floodplain.

3.2.5 Option 5a - Flood Storage (via channel amalgamation)

A flood storage area would be created on the airfield by removing the bank between Cross Rhyne and Hutton Moor Rhyne (which run parallel) along approximately 1.5km of channel. Storage potential could be maximised through the use of the culvert at Winterstoke Road and by limiting the discharge through the residential area of Uphill.

3.2.6 Option 5b – Flood Storage (as in 5a) plus recreation lake and wetland area

The flood storage area as in 5a above would be created and an additional area of flood storage provided on the grazing land to the south of the airfield site immediately adjacent to Hutton Moor Rhyne. This storage would be divided to form a recreational lake, as outlined in the Weston Vision document and an area of wetland with allowance for seasonal inundation. As well as providing flood risk mitigation measures, the lake and wetland areas would provide community benefit through the provision of amenity and recreational areas as well as creating a more diverse habitat.

3.2.7 **Option 6 – Culvert Works and Flood Storage (as in 5a)**

This option would create additional flood storage in the area of the airfield by opening up the 1km culvert which crosses the airfield and replacing it with a two stage channel. This would also improve access for maintenance and would eliminate the risk of localised flooding due to culvert blockage. It is anticipated that this storage would not be sufficient on its own, especially as it is towards the upstream end of the catchment, so this option would also include the storage area outlined in Option 5a.

3.2.8 **Option 7 – Pumping, Culvert Works and Flood Storage (as in 5a)**

A new pumping station would be installed in the vicinity of Uphill Sluice. The pumping station would operate during high flows when the sluice is tide locked. The pumping station could also be used during high flows when there is not tide locking to draw down water levels in the area. This would create a steeper hydraulic gradient so that water would actually drain quickly from the river and rhyne system.

To provide a better standard of protection, this option would also comprise the culvert works and flood storage as outlined in Option 5a and 6. The pumping station would require annual maintenance and the pumps would need replacement every 25 years.

3.2.9 **Option 8 – Sustainable Drainage Systems (SUDs)**

Traditionally when a site is developed, impermeable surfaces such as roads, houses and patios are created. Following rainfall events, runoff from these areas is collected into a piped system and drained to nearby watercourses. This system means that the rain water reaches the watercourse more quickly than it would have previously, leading to more frequent and severe flooding downstream. Sustainable Drainage Systems (SUDs) seek to limit the impact of development on surface runoff by mimicking natural processes and slowly releasing water, as would have occurred before urbanisation. This is achieved by the use of a variety of measures including soakaways, swales and permeable paving blocks.

This is not a direct flood defence option but seeks to prevent development from increasing the flood risk. A coherent system, should however be investigated prior to numerous developers making individual planning applications, as this will ensure that the correct guidance is given to developers with a view to achieving a system that meets catchment wide objectives as well as being easy and relatively inexpensive to maintain in a consistent manner.

3.2.10 **Option 9 – Flood Storage (as in 5b) and Flood Walls (as in 4)**

The flood storage areas outlined in 5a and 5b would be provided to attenuate upstream flows in the Cross Rhyne catchment. Flood walls would also be constructed adjacent to the built up areas in the upstream section of the Uphill Great Rhyne catchment along a 1.5km stretch. Due to the proximity of existing buildings it is unlikely that there will be sufficient access for the creation of earth embankments.

3.2.11 **Option 10 – Diverted Cross Rhyne with online lake, wetland area and culvert works**

Flows from Cross Rhyne would be diverted along a new channel starting at the old airfield pumping station and running through an area of wetland and then into a lake providing online storage and recreational facilities. The lake would also be fed from the freshwater stream which flows into Hutton and Locking Rhyne to help to maintain water quality. Flow leaving the lake would be throttled at the downstream end near to Winterstoke Road. Flow from the airfield and former airfield culvert (which would be opened up and replaced with a two stage channel) would drain into the existing Cross Rhyne and Hutton Moor Rhynes running south of the airfield.

3.3 River Banwell, Moorland Drove, West Wick and Way Wick Rhyne

3.3.1 **Option 1 - Do Nothing**

This option considers the cessation of all flood defence activities in the study area as a baseline for comparison of other options. Although potentially unrealistic, this is the baseline assessment option against which all other maintenance and capital options are compared, in accordance with both Defra and Treasury guidance.

Under this option, New Bow sluice would not be operated and all maintenance along the channel would cease. Operation of structures and maintenance carried out by the West Mendip Internal Drainage Board, including work to the structures in the adjoining rhyne system would also stop.

3.3.2 **Option 2 - Do Minimum/Existing**

Under this option, the River Banwell and nearby watercourses would be maintained by the Environment Agency and WMIDB as they are at present. Water control structures such as New Bow Sluice and smaller penning structures would continue to be operated to manage water levels and control flooding.

Existing flood banks and flood defence structures (New Bow Sluice) would be repaired or replaced at the end of their useful life. It is assumed that work will be carried out every 25 years at New Bow Sluice to replace mechanical and electrical components.

3.3.3 **Option 3 - Flood Warning**

This option would require the installation of a flood warning gauging station on the River Banwell. Due to the complex nature of the hydrology in the catchment, comprehensive modelling would also need to be undertaken. The gauge and modelling information would then be used by the Environment Agency to assess when flood warnings are necessary and to enable them to issue flood warnings. It should be noted that these warnings would apply only to fluvial flooding as tidal flooding would be caused by a failure of the sluice, which would not be possible to predict with sufficient lead time. This option will not increase the standard of protection for properties in the flood plain, but could potentially reduce flood damages.

In view of the relatively slow response time of the catchment it is likely that a flood warning lead time of at least three hours could be achieved, however, faster response times from the urban areas may reduce this. Tidal flood warnings are already issued for Weston-super-Mare by the Environment Agency.

3.3.4 **Option 4 - Flood Banks / Walls**

Flood banks would be constructed along the River Banwell to increase the channel capacity and protect property from flooding. The banks would be set back as far as

possible so as not to restrict functional floodplain. In some areas adjacent to development there is insufficient space for flood banks so flood walls would be used instead. The extents and heights of flood banks required, should this option be progressed further will be determined from the modelling. We have created 8km of flood banks / walls within the model based on an option outlined in the River Banwell Flood Study Report, Mouchel, 1996 which recommended flood banks / walls both upstream and downstream of the motorway.

3.3.5 **Option 5a - Flood Storage (Banwell Moor)**

Flood storage on Banwell Moor would be formalised by enclosing the current flood plain with an earth embankment. Additional structures could be built to control the water entering and leaving the flood storage area and a side spill weir could be used to allow water into the storage area with a sluice/penning structure to release the water once the level in the Banwell had subsided.

For all storage options annual maintenance and operation will be needed for the new control structures. In addition, replacement of electrical and mechanical systems and components parts will be necessary every 25 years.

The flood storage options have the potential to reduce the food risk but also provide mixed use amenity areas through activities such as bird watching, sailing or fishing. The socio-economic benefits that could be derived from such a scheme may be sufficient to attract financial contributions from bodies such as the EU Life Fund and RSPB. In view of the potential benefit of these flood storage areas it is recommended that suitable land be safeguarded for the future through mechanisms such as the Area Action Plan.

3.3.6 **Option 5b - Flood Storage (Banwell Moor) (as in 5a) and Flood Banks/Walls (as in 4)**

It is anticipated Option 5a will be insufficient to provide protection to either the developed areas downstream of the motorway or new development. This option therefore encompasses not only the flood storage area as outlined in Option 5a but also flood banks/walls. Flood banks/walls would be constructed downstream of the motorway to protect the residential areas. As for Option 4, the banks would be set back as far as possible so as not to restrict functional floodplain, and in places flood walls could be necessary.

3.3.7 **Option 6a - Flood Storage (Banwell Moor and New Bow) (as in 5a)**

As for Option 5a, a flood storage area would be created on Banwell Moor. A second area would also be created downstream of the motorway, with the size and location determined by detailed hydraulic modelling based on the interaction between fluvial flows and high tides. A possible location would be adjacent to New Bow Sluice. This option would increase the current area of flood storage that was constructed in the 1990s at the same time as the construction of New Bow Sluice. With the issue of tide locking it may be preferable to have the flood storage operating relatively frequently which would preclude activities such as farming. This, therefore, may be an area that could be used for environmental enhancement such as wetland creation.

3.3.8 **Option 6b - Flood Storage (Banwell Moor and New Bow) and Flood Banks / Walls (as in 5b)**

This option combines both storage as outlined in Option 6a, and flood banks to protect residential areas. As outlined in Option 6a, two storage areas would be created (formalisation of storage on Banwell Moor and storage area adjacent to New Bow

sluice). As for Option 5b, flood banks would be constructed downstream of the motorway to protect the residential areas.

3.3.9 **Option 7 - Channel widening**

Channel modifications would be undertaken to widen the channel and thereby increase channel capacity and provide storage within the channel. This would be achieved by removing material from the river and re-profiling the banks. Excavated material could be used to raise the banks in places.

Widening would be carried out for approximately 6km of the river between New Bow Sluice and Waterloo Farm (2 km east of the motorway)

There are also a number of structures along the river Banwell which at present create slow restrictions. The structures listed below would require modification (bridges) or removal (hatch abutments) under this scheme:

- Moor Lane Bridges
- Rolstone Farm Bridge (field access)
- Ebdon Hatch abutments

3.3.10 **Option 8 - Pumping Station, Flood Storage (as in 6a) and Flood Banks / Walls (as in 4)**

A new pumping station would be installed in the vicinity of New Bow. A storage area would also be created. The pumping station would operate when New Bow sluice is tide locked. The pumping station could also be used during high flows when there is not tide locking to draw down water levels in the area. This will create a steeper hydraulic gradient so that water will naturally drain more quickly from the river system.

To provide a better standard of protection, this option would also comprise flood storage and flood banks as outlined in Option 6b. The pumping station would require annual maintenance and the pumps would need replacement every 25 years.

3.3.11 **Option 9 - Diversion Channel**

This option seeks to create a flood diversion channel from the River Banwell to the Congresbury Yeo. The land between the River Banwell and the Congresbury Yeo is very flat so pumping may be required to create a hydraulic gradient to enable water to flow along the diversion channel. The distance between the rivers is 1.3km at the downstream extent of the Banwell, however this increases to approximately 2.5km near the M5 motorway. The most suitable point of abstraction on the Banwell, along with environmental and social factors, would have to be considered should this option be developed.

This new channel, pumping stations and structures would require annual maintenance and replacement of electrical and mechanical components would be necessary every 25 years.

3.3.12 **Option 10 – Sustainable Drainage Systems (SUDs)**

Traditionally when a site is developed, impermeable surfaces such as roads, houses, patios are created. Following rainfall events, runoff from these areas is collected into a piped system and drained to nearby watercourses. This system means that the rain water reaches the watercourse more quickly than it would have previously, leading to more frequent and severe flooding downstream. Sustainable Drainage Systems (SUDs) seek to limit the impact of development on surface runoff by mimicking natural processes and slowly releasing water, as would have occurred before urbanisation. This

is achieved by the use of a variety of measures including soakaways, swales and permeable paving blocks.

This is not a direct flood defence option but seeks to prevent development from increasing the flood risk. A coherent system, should however be investigated prior to numerous developers making individual planning applications, as this will ensure that the correct guidance is given to developers with a view to achieving a system that meets catchment wide objectives.

3.3.13 **Option 11 – Compound Channel**

A compound channel would be constructed downstream of the M5 motorway with a lowered bank extending laterally for 50m on the right bank of the channel over a 1900m stretch of channel. This will provide additional storage and lower water levels locally at times of high flow with minimal disruption to the existing agricultural land use (grazing). At certain points along the left bank of this channel the defence is known to have low points which would require a small increase in elevation.

3.4 Overview of Hydrology and Modelling

3.4.1 The aim of the hydrological study was to obtain the most realistic flows possible using available observed flow, stage and rainfall data. The differing characteristics of the sub-catchments require an approach that simulates the relative timings of the response to rainfall on the Uphill Great Rhyne and Banwell catchments. This enables representation of the development of the event hydrograph storm throughout the catchment, as well as showing the affects of attenuation and potential tide-locking. Therefore inflow hydrographs were produced for each of the significant sub-catchments draining to Uphill Great Rhyne and Banwell watercourses for both pre and post development scenarios. To assess joint probability the tide curve for Highest Astronomical Tide with a fluvial flow of a 100 year return period was used.

3.4.2 Full details of the stage and rain gauge data, tidal boundary data, estimation of surface water run off for pre and post development as well as inflow hydrographs can be seen in the modelling reports in Appendix C and D.

3.4.3 Following guidance from the Environment Agency, West Mendip Internal Drainage Board and PPS25, a 20% increase in peak rainfall intensity and fluvial flows is considered appropriate to take account of the effects of climate change until 2085. This increase in flows has been taken into account with the creation of potential flood extents and must be accommodated within the design of any flood defence structures. An additional 10% increase in flows has also been included as a precautionary approach and to provide allowance for the uncertainties of modelling a rhyne system.

3.4.4 Model runs were also carried out for Q100+0% flows and Q100+50% flows for sensitivity testing purposes and to provide additional comparable data to assist in the verification of other studies and Flood Risk Assessments within this area. Detail of these results can be found the modelling reports in Appendix C and D.

3.4.5 The objective of the hydraulic modelling was to provide a tool to assist the estimation of water levels for the preparation of flood risk maps for both catchments. An unsteady-flow model was used to allow for the spatial and temporal distribution of flood water volume, thereby giving greater confidence in the results. The model was built using HEC-RAS, an industry-standard package used to model open channel and floodplain flow, whilst incorporating hydraulic units such as bridges, weirs and sluices. HEC-RAS computes

flow depths and discharges using a method based primarily on sub critical flow regime calculations. This enables an accurate representation of the flow into and out of the storage areas.

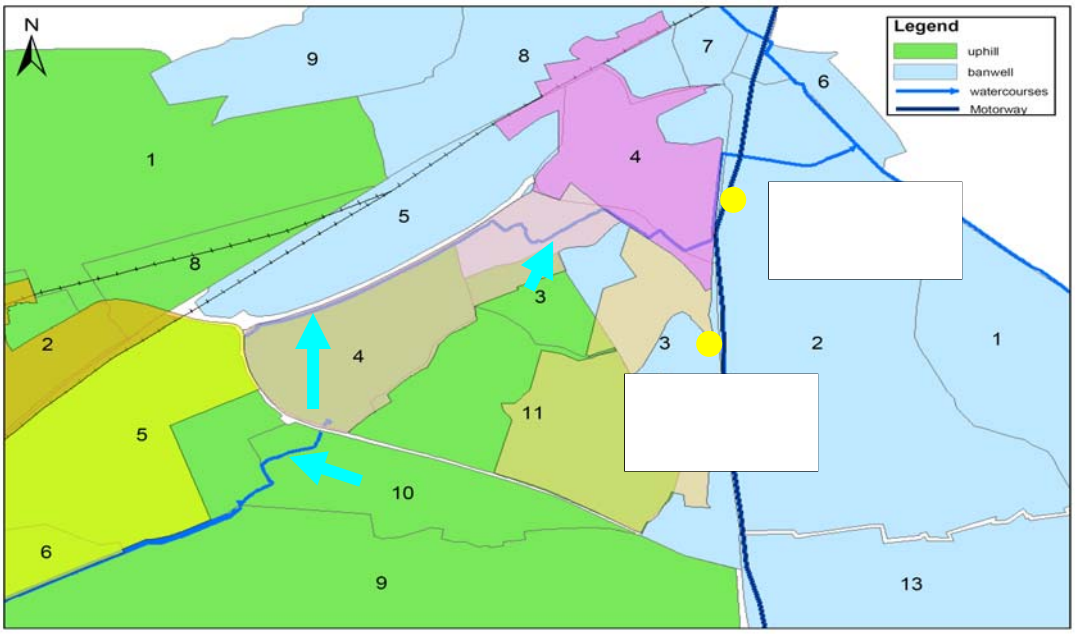
3.4.6 Full details of the topographic survey data, model schematics, roughness coefficients, boundary conditions, critical storm duration, calibration and sensitivity testing can be seen in the modelling reports in Appendix C and D.

3.4.7 Following guidance from the Environment Agency and the West Mendip Internal Drainage Board, winter un-penned levels were used in determining the channel hydraulics and the summer penned levels were used in the appropriate storage areas within the model. This combination of penning regimes allows for the worst case scenario and also takes account of the potential effect of summer convective storms on reduced levels of storage.

3.5 Cross catchment flows

3.5.1 The effect of transferring flows from the Uphill Great Rhyne catchment to the Banwell catchment was assessed in order to potentially reduce the impact of increased surface water flows due to development on the Uphill Great Rhyne watercourse system. Additional flows would need to be routed under the M5 motorway using one of two existing routes; the large culvert on West Wick Rhyne near to junction 21 and the 1200mm culvert on Blind Yeo Rhyne near to Wolvershill Bridge north of the former RAF Locking site. The locations of these culverts and the sub catchments are shown on figure 3.1 below.

Figure 3.1
Cross catchment overview with key development areas



West Wick Rhyne culvert

3.5.2 Flows from the Uphill sub-catchments 3, 4 and 11 were input into the Banwell model by introducing them to the Banwell Tributary model and only the flows from sub-catchment 10 were input at the top of Cross Rhyne. These additional flows result in an additional

136,400m3 of water being conveyed by the Banwell tributary for the modelled 1 in 100 year event.

3.5.3 For the Uphill catchment, channel water levels were only significantly affected near the upstream extent of Cross Rhyne with a few cross sections showing level decreases of 20-90 mm, with up to 10 mm level reductions on the rest of the reach and a few 10 mm changes on Uphill Rhyne. The majority of storage area levels only decreased by a few cm with the largest reductions in level, of 160 mm occurring in storage area 2 and a 9cm reduction in the levels in storage area 19.

3.5.4 The resulting water levels in the tributary were raised by 80-90 mm in most places with a few increases of 100-110 mm. On the Banwell River itself the water levels varied by 0-30 mm. The water levels at the New Road Store, M5 Marsh Store and the Moor Dr Store have all increased by 80-90 mm. There was a general increase in storage area levels (Banwell Moor 1 and Banwell Moor 2 of up to 100mm).

3.5.5 There is limited spare capacity in the Moorland Drove Rhyne at present and the diversion of additional flows, following development in the Moor Lane area, would compromise the freeboard in this watercourse. Therefore flows would need to be routed via another channel to reach West Wick Rhyne to the south of Somerset Avenue. At this stage of development we do not believe that the diversion of flows would be viable.

Blind Yeo Rhyne culvert

3.5.6 There are two culverts at this location, the upstream section being 1050mm in diameter and extending for 70m followed by a larger culvert of 1200mm extending for 180m. Using elevations from the LiDAR data and typical channel cross sections a hydraulic model was built to assess the maximum flow that can be conveyed by this culvert system before overtopping occurs. This was found to be 0.8m3/s. The culvert is also believed to be submerged 80% of the time as outlined in information provided by the WMIDB. Therefore there is virtually no spare hydraulic capacity within this culvert system unless significant works are undertaken.

3.5.7 Detailed information regarding changes to inflow locations and model schematic details regarding the above cross catchment flows can be found in the modelling reports in Appendix C and D.

3.5.8 The total additional run off volume due to development for the Banwell catchment is 68,000m^3 and for the Uphill catchment 234,000m^3 for the modelled 1 in 100 year event.

3.6 Assessment of additional volume of storage required due to development

3.6.1 As the proposed developments on the study area would lead to an increase in impermeable land, this increase in urbanisation was factored into the Phase I hydrology to produce post-development flows. For this study a hybrid methodology was used through the assessment of land use coefficients from the Modified Rational Method and application of an adjusted Standard Percentage Runoff (SPR) value to the runoff rates already identified in Phase I using the Flood Estimation Handbook Rainfall Runoff Method. A more detailed methodology can be found in the modelling reports in Appendix C and D.

3.6.2 As land in the key development areas of the Airfield and Rhynes Neighbourhoods is within the fluvial floodplain (as identified by the hydraulic modelling from this study) an

assessment of the volume lost from these storage areas due to development has been made. This assessment assumes that 100% of the lost volume enters the catchment as run-off with no on site attenuation.

3.6.3 The volume lost has been calculated for water levels taken from the Q100+30% post development flows by adjusting the LiDAR Digital Terrain Model (DTM) data for the proposed development extents and therefore building works above ground level. Where applicable detailed site layout plans have been taken into account. Otherwise 100% of the area is assumed to be developed. These volumes are given in table 3.2 below.

Table 3.2
Volume lost due to development

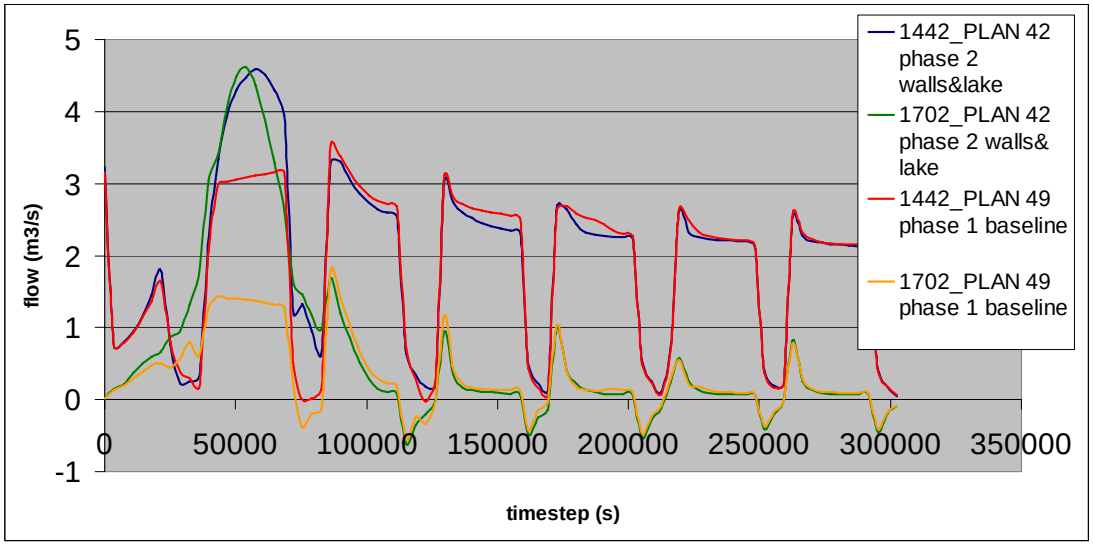
Development Area	Level achieved from Q100+30% flows	Volume lost due to development within the floodplain
Airfield Neighbourhoods	4.94mAOD	69,500m^3
Rhynes Neighbourhoods	5.04mAOD	115,000m^3

3.6.4 For Uphill Great Rhyne, Option 4 (Flood Banks/Walls) and Option 9 (Flood Storage (as in 5b) and Flood Banks/Walls), further additional volumes were calculated by the assessment of cross section data. The provision of walls and the associated increase in flow and water levels and therefore volume also need to be factored into storage provision to prevent out of bank flows in the downstream section of Uphill Great Rhyne south of the hospital and through Uphill village.

3.6.5 These volumes were obtained by calculating the area under the hydrographs and comparing the peak flows for pre and post development taken from a sample of cross sections within the model. These sections were chosen due to their location relative to the proposed storage areas and proposed flood banks/walls. Figure 3.2 shows a comparison of two locations with the volume difference between pre and post development being 44,856m^3 for cross section 1442 and 107,064m^3 for cross section 1702.

3.6.6 The additional volume from loss of floodplain and provision of walls have been used to make an assessment of the maximum level of attenuation required across the Weston Development Area as a whole and considers the whole life of the development. They do not follow a phased development approach as the detailed site extents for each specific stage of development are not available at this time. We therefore recommend that continued hydrological assessments are made taking account of the effect of development. These can then be incorporated into the baseline model to provide a dynamic overview of the changing catchment and its response to increased runoff rates.

Figure 3.2
Uphill catchment: Comparison of pre and post development flows



*numbers in the key above refer to cross section chainage in the model

3.7 Additional flows

3.7.1 There is a possibility that additional surface water flows currently discharging through the Uphill Great Rhyne catchment as sewer flows may be re-routed in part into the rhyne system. It is expected that Wessex Water will be able to provide an assessment of expected flows for the 100 year return period by spring 2007 and an additional hydraulic study may be commissioned to identify the effect this will have on the catchments as a whole.

4 ENVIRONMENTAL SURVEYS

4.1.1 This section provides an overview of the environmental surveys carried out as part of this study in order to inform the environmental baseline, for use in Environmental Impact Assessments, and to inform the flood mitigation options proposed in Section 5. It provides a brief description of each of the surveys undertaken, the results found and the key opportunities for environmental enhancement. Detailed environmental data can be found in Appendix H.

4.2 Survey Methodology

River Corridor Survey

4.2.1 A River Corridor Survey was undertaken in May 2006 on 6km of the River Banwell, and 6km of the Cross Rhyne and Uphill Great Rhyne. The survey followed the methodology set out in the New Rivers and Wildlife Handbook (RSPB *et al*, 1994) where continuous 500m sections of the watercourse are walked and all features of interest mapped. The results of the River Corridor Survey are presented in Appendix H1.

Extended Phase 1 Habitat Survey

4.2.2 An extended Phase 1 Habitat Survey was carried out in May 2006 on 6km of the River Banwell, 6km of the Cross Rhyne and Uphill Great Rhyne, the proposed river diversion and proposed flood storage area. The standard methodology was followed (JNCC, 1990) where the site plus a 200m buffer are walked, habitats mapped, and target notes taken to list species and features of interest. The survey also included a search for signs of and suitable habitat for protected species including otter, water vole, badger, and great crested newt. The results of the Extended Phase 1 Habitat survey are presented in Appendix H2.

Fisheries

4.2.3 Five sites on the Uphill Great Rhyne and River Banwell catchment were surveyed by North Wessex Ecological Appraisal Team as part of the Weston Flood Management Scheme between 17th October 2006 and 20th April 2007. Surveys were conducted using 240v pulsed D.C. electric fishing over a distance of approximately 100m. Apart from ‘minor species’ such as sticklebacks and stone loach, all fish were identified, weighed and measured. Approximate figures are given for minor species (e.g. 1 - 9, 10 – 99, etc.). The results of the fisheries survey are presented in Appendix H3.

Water Quality

4.2.4 Water quality data for the River Banwell, St Georges STW-Sea, was provided by the EA and is included in the Agency’s General Quality Assessment scheme (GQA). Water sampling on the Cross Rhyne and Uphill Great Rhyne was carried out by Royal Haskoning. Sampling was undertaken monthly over a period of 12 months to provide a baseline for water quality for these watercourses. The parameters investigated were the eight parameters that together form a ladder of increasing quality to reflect the needs if communities of plants and animals in our rivers as set out in The Surface Waters (River Ecosystem) (Classification) Regulations 1994, SI 1994 No. 1057. The system comprises five classes in order of decreasing quality, from RE1 (highest) to RE5.

The eight parameters investigated were:

- Biological Oxygen Demand (BOD);
- Ammonia;
- Dissolved Oxygen (DO);
- Un-ionised Ammonia;
- pH;
- Hardness;
- Dissolved Copper; and
- Total Zinc.

4.2.5 Samples were sent to the EA's Starcross laboratories (last two months samples were sent to the centralised Leeds EA laboratory) to ensure they achieve the EA specifications. Dissolved oxygen (DO), suspended sediments, temperature, and pH were measured on site using appropriately calibrated meters. The chemical water quality results are presented in Appendix H4.

4.2.6 The biological assessments of the Uphill and Cross Rhynes were based on a survey of macro-invertebrates. The Environment Agency's General Quality Assessment data on the neighbouring Banwell Stream provides a baseline biological condition of a typical watercourse in the region.

4.2.7 The Biological Monitoring Working Party (BMWP) score method was used to assess the biological condition of the watercourses. The BMWP Score system assigns a numerical value to different taxa taking into account that some animals are more susceptible to organic pollution than others; those that are intolerant to pollution have high scores and those that are tolerant to pollution have low scores.

4.2.8 Biological data are assessed by the number of taxa present and the average score per taxon (ASPT). The ASPT is the average of the values for each taxon in a sample and is a stable and reliable index of organic pollution. Good quality sites are indicated by a diverse variety of taxa, especially those that are sensitive to pollution. The BMWP score is also presented. The biological survey results are presented in Appendix H5.

4.2.9 For the purpose of this study, the BMWP and ASPT scores allow the types of animals collected at a site to be compared with the water chemistry assessed.

4.2.10 Following EA protocol two biological samples were collected for each site, one in spring (May 2006) and one in autumn (October 2006). Each sample was taken with a kick net, which was swept in the vegetation and substrate for a period of three minutes. The collected invertebrates were identified in-situ with the assistance of a hand lens and identification books. Population size of each taxon was not recorded.

4.2.11 Observations on the physical habitat template were made using the River Habitat Survey spot-check method as a basis for assessment. This also included environmental variables such as water flow.

4.3 Results

4.3.1 All sites have a modified, re-sectioned channel. The Uphill Great Rhyne housing estate site has an artificial substrate with brick banks, the footbridge site has a silt substrate and clay banks, and the Cross Rhyne site has silt substrate and earth banks. All sites have trash deposited in the channel, the Uphill Great Rhyne housing estate site was

particularly choked with discarded household items. Emergent vegetation is present at all sites and dominates the vegetation structure. Filamentous algae were present in the Uphill Great Rhyne housing estate site.

4.3.2 The River Corridor Survey and Phase 1 Habitat Survey did not identify any flora of note. No signs of otter, water vole or badger were observed during these surveys, although a potential otter run was found on the River Banwell. The habitats noted within the survey area are of local nature conservation interest as they are frequent within North Somerset.

4.3.3 The electric fishing survey revealed that no species of designated ecological importance (such as Atlantic salmon, lamprey or bullhead) were present at these sites and coarse fish predominated. Overall, species diversity and numbers of individual fish was low, particularly on the Uphill Great Rhyne. Most of the species recorded are tolerant to a wide range of environmental conditions, including some forms of pollution.

4.3.4 Water chemistry analysis demonstrated that the Uphill Great Rhyne and Cross Rhyne have poor water quality due to very low levels of dissolved oxygen (DO). Oxygen is a necessary element to all forms of life and the amount of dissolved oxygen in the water is a factor in determining the species and abundance of organisms present. DO was found to be higher in the River Banwell and this is reflected in the greater diversity of macro-invertebrates recorded in the here compared to the rhynes.

4.3.5 The relatively low BMWP and ASPT scores of the watercourses, particularly both rhynes, indicate that the invertebrate assemblage is affected by water quality. The growth of macrophytes and features at all sites is providing sufficient habitat, therefore the assemblage is unlikely to be constrained by physical parameters.

4.3.6 Results from the macro-invertebrate survey visits and the water chemistry analysis indicate that the water quality is poorest in the Uphill Great Rhyne housing estate site. This indication is supported by the presence of filamentous algae in this reach of the watercourse, which was not observed in the other two sites. The housing estate site does not support any invertebrates with a BMWP score greater than 6 (*Gammaridae*), whereas species with scores of 7 and 8 were found at the other two sites. No invertebrate species of significant conservation interest were encountered during the survey.

4.4 Key opportunities for environmental enhancement

4.4.1 There are many opportunities for enhancement of the Uphill Great Rhyne and Cross Rhyne system and the Banwell as part of flood risk management which have been reviewed as part of the Options review in Section 5. Key opportunities are to:

- Improve the amenity and landscape value of the rhyne network including a reduction in fly-tipping and maintenance of traditional landscape features;
- Increase flow and morphological diversity along the river;
- Improve marginal and riparian zone habitat conditions;
- Reduce agricultural diffuse pollution entering the river;
- Incorporate the creation of wetlands in measures to manage flood risk;
- Improve water level management taking into account flood risk management and agricultural needs; and
- Encourage local community interaction with the rhyne network as a community resource.

5 PREFERRED OPTIONS

5.1 Evaluation of Options

5.1.1 Table 5.1 summarises the potential effects of each option on flood risk and the impacts on environment, human environment and economics factors and any associated opportunities and constraints. This is to provide a summary of the benefits and restrictions of each option and provide an account of the reasoning used to identify the preferred option/s for each catchment area. Those options that have been taken forward are shaded in green. A more detailed evaluation can be found in the tables in Appendix E.

Table 5.1
Evaluation of options

Option	
Uphill Great Rhyne and Cross Rhyne catchment	
1.Do Nothing	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
2.Do Minimum/Existing	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. No major environmental constraints have been identified though environmental enhancement is recommended. Development would be allowed contrary to PPS25 policy.
3.Flood Warning	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. The hydrograph peak due to increased surface water runoff does not have sufficient lag time to allow operation of a flood warning system. Flood mitigation measures will need to be implemented. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
4.Flood Banks/Walls	This option is not viable due to other flood mitigation options having a more beneficial effect on the reduction of water levels. There are potential problems with accessibility, maintenance and cost particularly along reaches of the Uphill Great Rhyne. The length of walls required is not as extensive as first envisaged following analysis of the pre and post development water levels. The upstream benefit provided is not sufficient. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
5a.Flood Storage (via channel amalgamation)	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.

5b.Flood Storage (as in 5a) plus recreation lake and wetland area	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. Development would be allowed contrary to PPS25 policy. The concept of this option has been developed further into option 10 The location of the lake does not attenuate sufficient flows in order to reduce the flood risk in the upstream reach of Uphill Great Rhyne. No major environmental constraints have been identified.
6.Culvert Works and Flood Storage (as in 5a)	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. Development would be allowed contrary to PPS25 policy. No major environmental constraints have been identified. This option has been incorporated into Option 10.
7.Pumping Station, Culvert Works and Flood Storage (as in 5a)	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy. This option is against the aspirations of the Weston Development Area due to unsustainability (from Pumping Station), costs and associated maintenance.
8.Sustainable Drainage Systems (SUDs)	All development should adhere to North Somerset Councils central SUDs policy. Contributions to flood risk mitigation measure should make allowances for minimising run off and on site attenuation. No major environmental constraints have been identified. Development takes account of PPS25 policy.
9. Flood Storage (as in 5b) and flood banks/walls (as in 4)	This option has been developed and superseded by Option 10, which costs less and potentially reduces water quality issues to the proposed lake.
10. Diverted Cross Rhyne with online lake, wetland area and culvert works (replacing culvert with two stage channel	The combination of re-routing Cross Rhyne and providing additional storage through the creation of a lake and two stage channel in the location of the former airfield culvert provides sufficient attenuation and also reduces levels within the upstream reaches of UGR. No major environmental constraints have been identified. Development takes account of PPS25 policy. There is potential for significant environmental enhancements.

Option	
River Banwell, Moorland Drove, West Wick and Way Wick Rhyne catchment	
1.Do Nothing	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy though the increased flood risk due to development is small in this area.
2.Do Minimum/Existing	This option has been followed across the majority of the Banwell catchment as the increased flood risk due to development is minimal in this area. No major environmental constraints have been identified though environmental enhancement is recommended. The risk is still evident but there are not sufficient properties to make it economically viable to develop a protection scheme for this area.
3.Flood Warning	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. Individual property protection is recommended via a programme of awareness and possible financial incentives. Flood mitigation measures will need to be implemented. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
4.Flood Banks/Walls	This option has been followed in part in the St Georges area just north of the M5 as there are several low points along the existing banks. The length of additional embankment required is not as extensive as first envisaged following analysis of the pre and post development water levels. No major environmental constraints have been identified.
5a. Flood Storage (Banwell Moor)	The location of the storage area does not have an impact on reducing increased flood risk. Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
5b. Flood Storage (Banwell Moor) (as in 5a) and Flood Banks/Walls (as in 4)	The location of the storage area does not have an impact on reducing increased flood risk. Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
6a.Flood Storage (Banwell Moor and New Bow) (as in 5a)	The location of the storage area does not have an impact on reducing increased flood risk. Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
6b.Flood Storage (Banwell Moor	The location of the storage area does not have an impact on reducing increased flood risk.

and New Bow) and Flood Banks (as in 5b)	Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
7.Channel Widening	The flood defence benefit is not deemed sufficient to make this option viable on the grounds of flood risk, economic factors (disposal of excavated material) and environmental factors (maximum impact and potential low flow issues). No major environmental constraints have been identified.
8.Pumping Station, Storage (as 6a) and Flood Banks (as 4)	This option is against the aspirations of the Weston Development Area due to unsustainability (from Pumping Station), costs and associated maintenance. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.
9.Diversion Channel	The flood defence benefit is not deemed sufficient to make this option viable on the grounds of flood risk, economic factors (disposal of excavated material) and environmental factors (maximum impact). No major environmental constraints have been identified.
10.Sustainable Drainage Systems (SUDs)	All development should adhere to North Somerset Councils central SUDs policy. Contributions to flood risk mitigation measure should make allowances for minimising run off and on site attenuation. No major environmental constraints have been identified. Development takes account of PPS25 policy.
11.Compound Channel	This smaller scale option is more appropriate to mitigating against the increased level of flood risk and provides fewer accessibility and maintenance issues compared to solely raising bank levels. It also is more cost effective (if the cost of the disposal of material is discounted). There is potential for significant environmental enhancements. No major environmental constraints have been identified. Development takes account of PPS25 policy.

5.1.2 The sketches in figures 5.1 and 5.2 present the evaluation of options in a different context through the use of opportunity mapping to provide and additional and powerful tool for screening, evaluating and ranking options in complex multi-criteria integrated decision making processes. Opportunity mapping linked to the impact categories of the Multi Criteria Analysis (MCA) methodology, together with a colour coding for the scale of impact provides greater transparency to the decision making process and can assist in actively engaging stakeholders.

Figure 5.1: Appraisal of early conceptual options for Uphill catchment

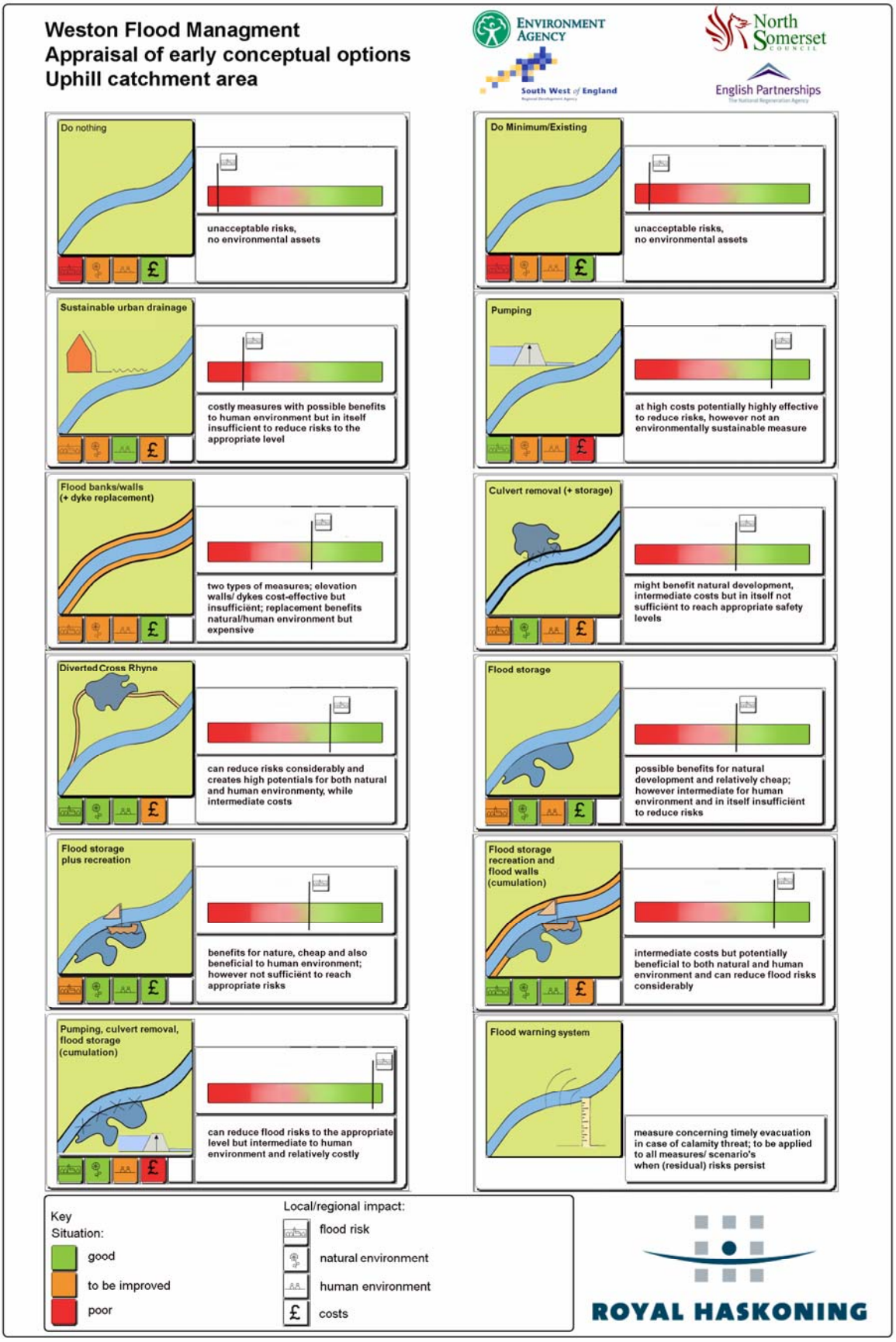
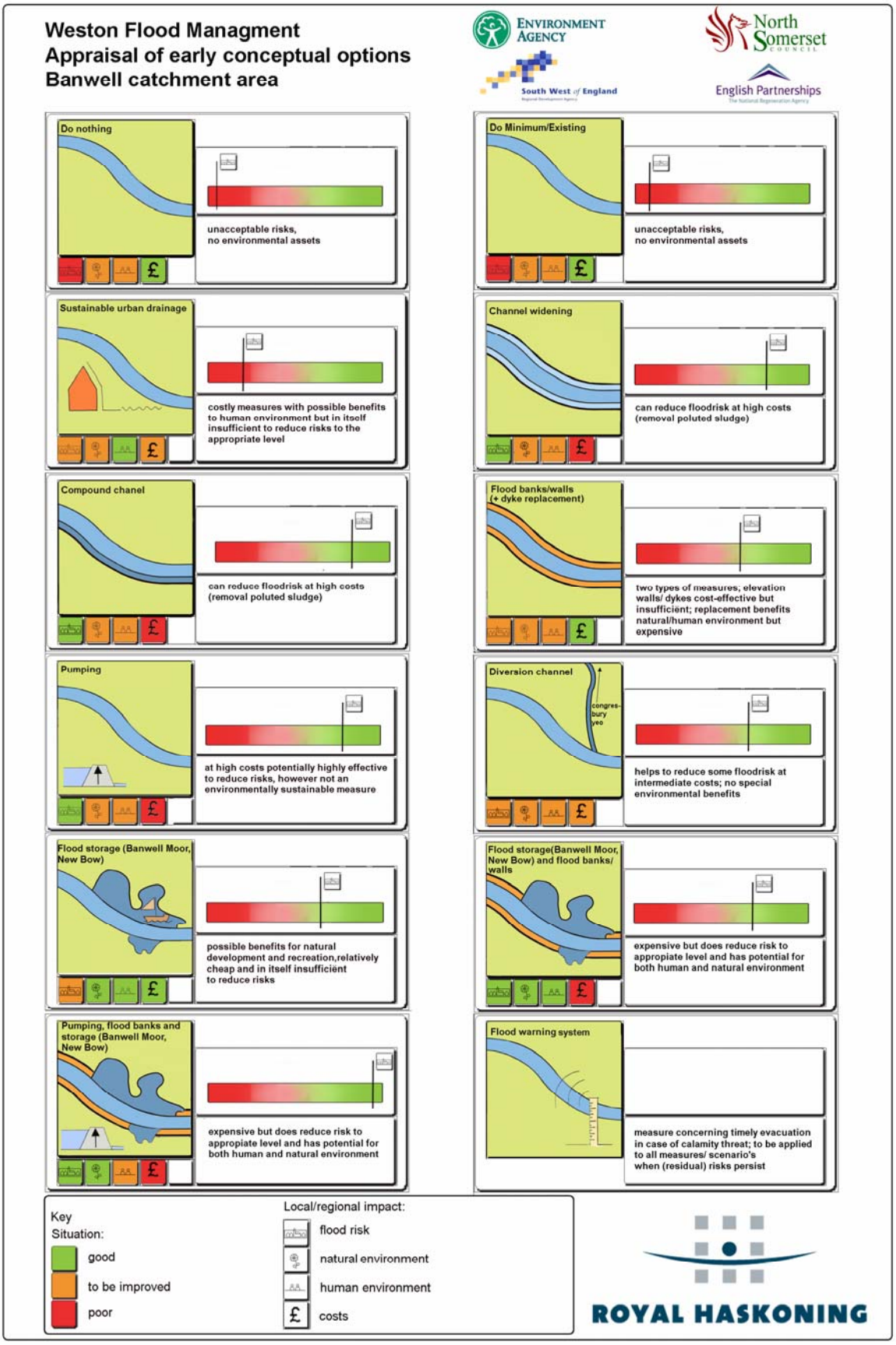


Figure 5.1: Appraisal of early conceptual options for Banwell catchment

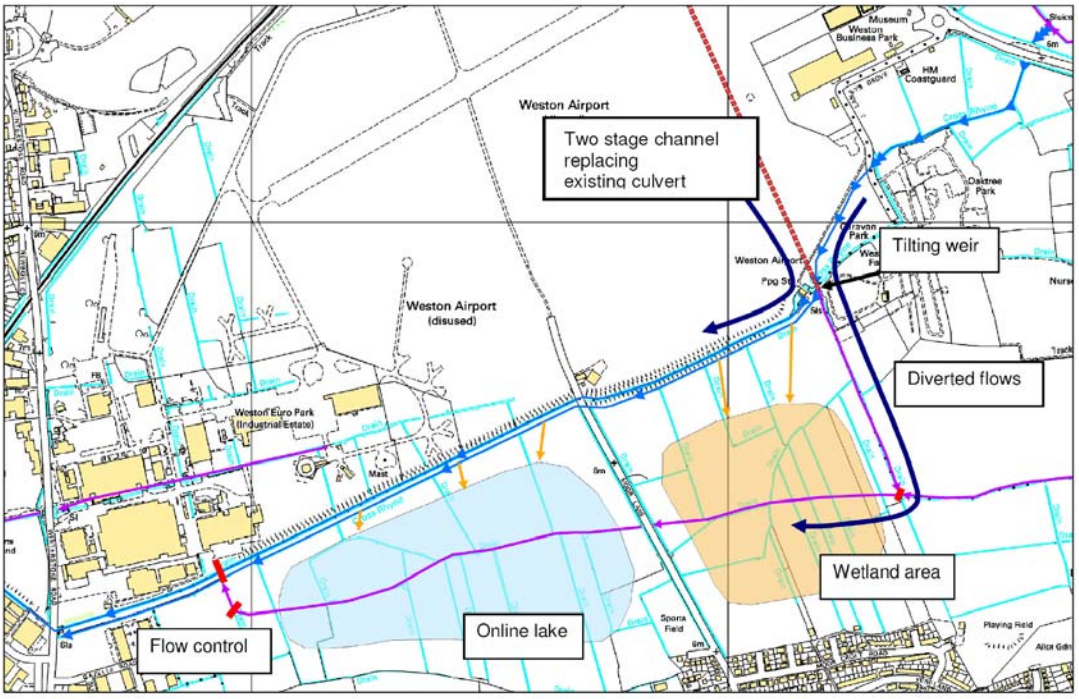


5.2 Preferred Option for Uphill Great Rhyne and Cross Rhyne catchment

5.2.1 The increased flood risk due to development is significantly more apparent within the Uphill and Cross Rhyne catchments. Due to the limitations of building additional and extended defences in the downstream and upstream reaches of Uphill Great Rhyne this preferred option seeks to provide sufficient storage to attenuate additional flows due to increased surface water runoff in the areas adjacent to the Airfield Neighborhoods development area.

5.2.2 Following discussions within the project team and wider consultation the preferred option is **Option 10-Diverted Cross Rhyne with online lake and wetland areas and culvert works**. The location and extent of this system is shown in drawing AA_0354 in Appendix B and the sketch in figure 5.3 below provides an overview. The detailed results output from the hydraulic model and model schematic can be seen in the modelling report in Appendix C. The option as modelled does not account for on site attenuation as it aims to prove that sufficient volumes can be attenuated through the provision of off site works. The size of the lake and new channels can be reduced according to the requirements of the Partnership, for amenity and recreation provision and the levels of attenuation adjusted accordingly. This option also considers the realignment of Cross Rhyne near to the campsite at the eastern edge of the airfield site.

Figure 5.3
Overview of diverted channel, online lake and adjusted culvert



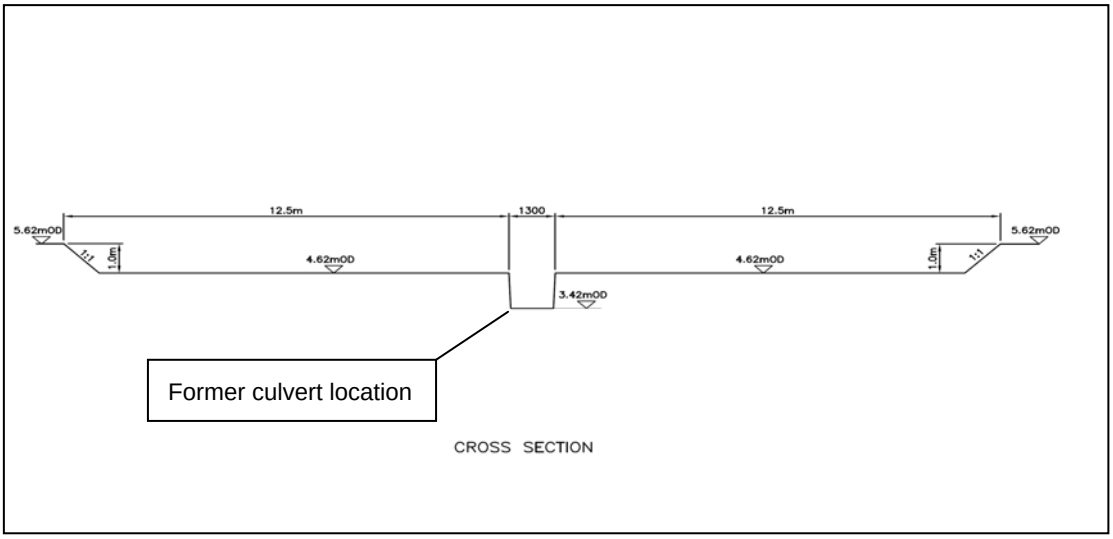
5.2.3 This option involves diverting Cross Rhyne at the former airfield pumping station to allow the flows to meet Hutton and Locking Rhyne which is spring fed to improve water quality. These combined flows will pass through a wetland area and then into an online lake which would serve as storage and will also provide amenity and recreation facilities and environmental enhancement. Flows from the lake rejoin Cross Rhyne after its convergence with Hutton Moor Rhyne and are throttled by a culvert at this location. Additional storage is provided by the creation of a two stage channel replacing the 1300mm culvert across the airfield site. This will also have a function as a green corridor

and access route to the proposed employment developments. The sketch in figure 5.4 indicates the profile of this two stage channel.

5.2.4 By diverting the flows from Cross Rhyne, the conveyance of flows following a rainfall event is sufficiently altered to allow flows from the upstream reach of Uphill Great Rhyne to pass through the system with increased efficiency. This leads to a reduction in the level of freeboard needed compared to the pre-development existing scenario. The freeboard is up to 400mm lower than the Environment Agency recommend at a few specific locations, however the areas that are subject to flood risk as a result of this are generally public open space and there is very limited risk to property. Therefore as flood risk would be reduced there is no need to construct flood walls.

5.2.5 Following the assessment of the additional volume of storage required due to development (section 3.4) and analysis of the hydraulic model, the minimum size of lake required is 170,000m^3 (loss of floodplain storage volume minus airfield two stage channel storage for increased run-off volumes) and the maximum needed is some 240,000m^3. Given that groundwater is assumed to be at the level of 4.0mAOD and making allowance for a sufficient boundary zone around the lake for recreation purposes this maximum lake size is achievable within the required location.

Figure 5.4
Former culvert cross section



Option costs

5.2.6 The cost of this option has been calculated at £4,900,000 and includes site investigation, set-up and prelims, service diversions and all works including bank raising. This cost assumes that excavated material will be transported and spread on adjacent land to a depth of 500mm approx. The annual maintenance charge is expected to be £70,000. This cost does **not** include for land purchase and compensation costs.

5.2.7 Should the disposal of material off site be necessary, landfill charges are expected to be in excess of £9m. This cost may be reduced through the use of more sustainable options such as the recycling of waste material for building works in the local vicinity as suggested in the costing given above (however the material is still subject to tax) or potential on-site disposal. A more detailed cost breakdown can be found in Appendix E.

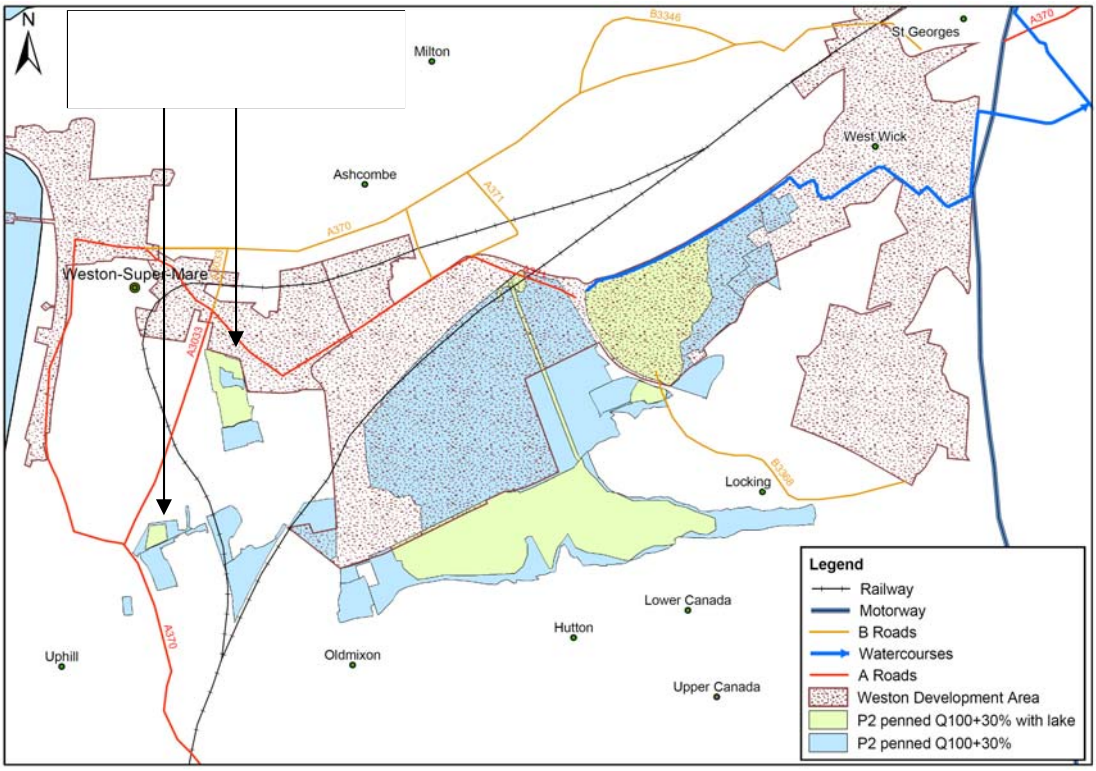
Properties at risk

5.2.8 If this option were adopted, only 4 properties would be at risk from potential flooding (at or above the 1% annual exceedence) after development. This is a substantial reduction from the 188 properties at risk post-development and before the implementation of flood risk mitigation options within the model to create revised extents.

5.2.9 These properties are located on the fringes of the newly defined flood extents and could be protected through individual property based protection schemes. We would recommend that these schemes are adopted and property owners encouraged to take up these measures through awareness schemes and financial assistance where possible. The flood extents taking account of this option are given in figure 5.5 with more detail provided in drawing AA_0401 in Appendix A.

5.2.10 Despite the considerable reduction in properties at risk and adherence to PPS25 guidelines the benefits are not sufficient to achieve a sufficiently high Defra priority score to provide grant aid funding assistance.

Figure 5.5
Uphill catchment: Flood extents after diversion of channel, online lake and culvert works with post development (P2) flows
(NB. Flood extents from the Banwell catchment are not shown on this figure)



5.3 Preferred Option for River Banwell, Moorland Drove, West Wick and Way Wick Rhyne

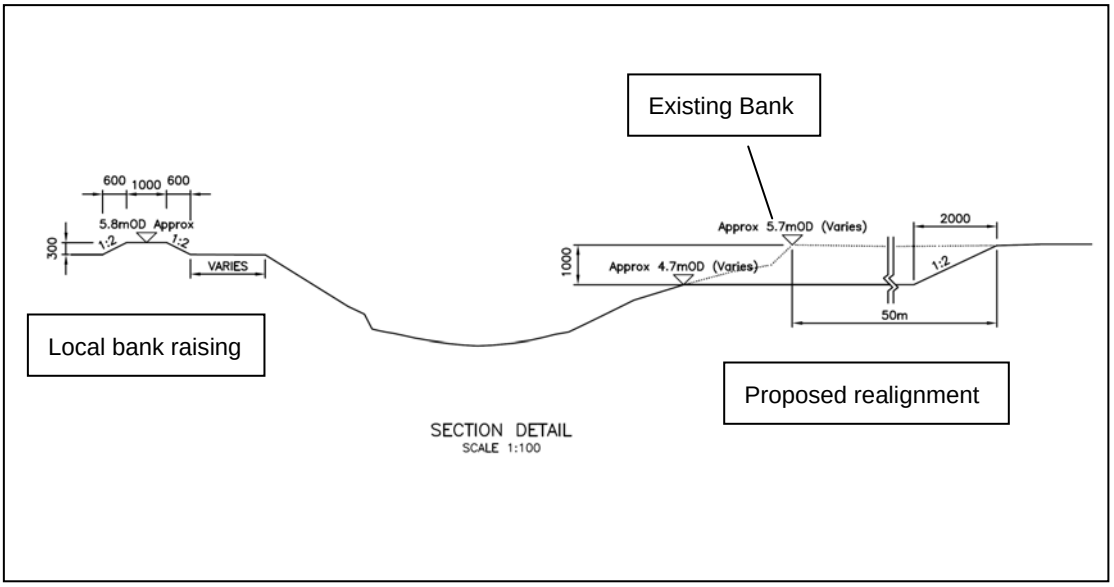
5.3.1 Overall on the Banwell catchment there is only a small increase in flood risk due to the proposed development as outlined under the Weston Vision. The flood risk mitigation strategy therefore aims to protect areas where there is a potential of increased risk to existing properties such as in the St Georges area to the north of the M5 motorway. At

the present level of development it is not felt that there are sufficient grounds in terms of potential flood risk to provide any formalised storage across the catchment. However this could be considered in the future as recommended in section 8.

5.3.2 Following discussions within the project team and wider consultation the preferred option is **Option 11- Compound Channel (with localised bank raising)**. The location and extent of this compound channel is shown in drawing AA_0303 in Appendix B. The detailed results output from the hydraulic model and model schematic can be seen in the modelling report in Appendix D. Option 11 applies to approximately 2km of the River Banwell. For the remainder of the catchment the preferred option is Option 2 - Do Minimum/Existing to maintain the current operational regime.

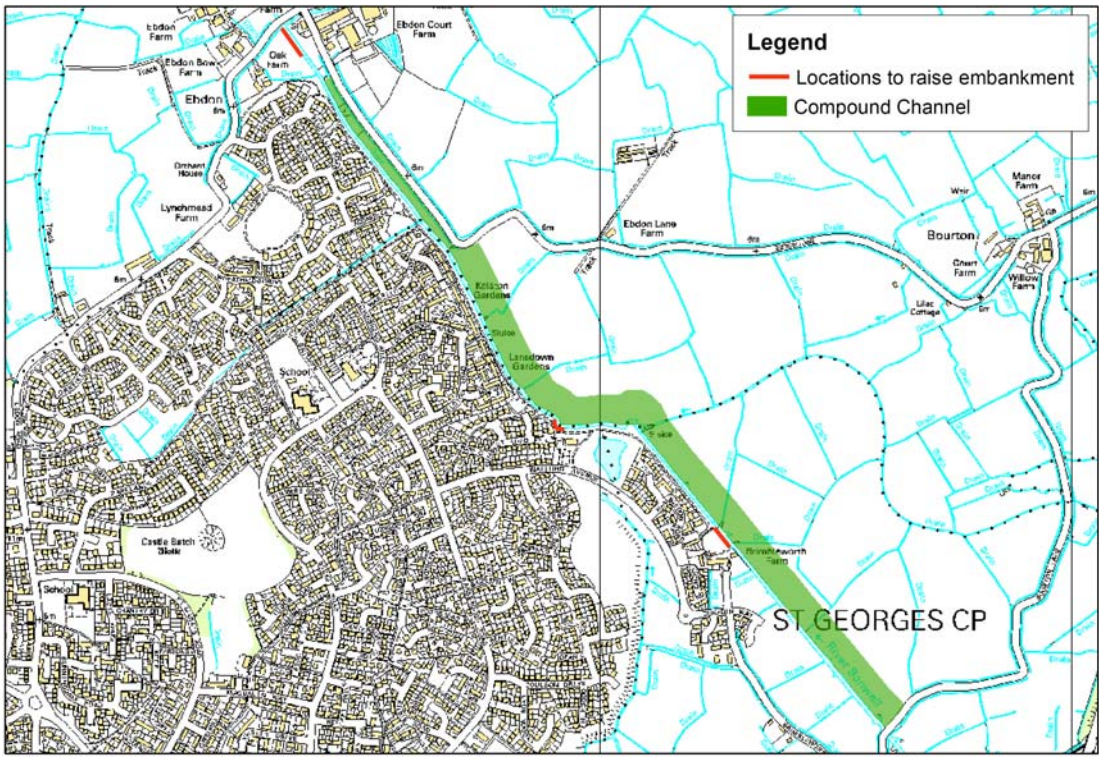
5.3.3 Option 11 involves building a compound channel downstream of the M5 motorway with a lowered bank extending laterally for 50m on the right bank of the channel over a 1900m stretch of channel. This will provide additional storage at times of high flow with minimal disruption to the existing agricultural land use (grazing). At certain points along the left bank of this channel the defence is known to have low points which may require a small increase in elevation to the existing banks. The sketch in figure 5.6 indicates the profile of this channel section.

Figure 5.6
Compound Channel cross section



5.3.4 There are three locations where the channel is known to have low points requiring the existing embankments to be raised by up to 300mm to ensure that the freeboard is not compromised. Material for this work could be brought in from the compound channel excavations if suitable. The length of bank to be raised totals 190m and the locations are identified on figure 5.7.

Figure 5.7
Banwell catchment: Location of compound channel and raised embankment work



Option Costs

5.3.5 The cost of this option has been calculated at £900,000 and includes site investigation, set-up and prelims, service diversions and all works including bank raising. This cost assumes that excavated material will be transported and spread on adjacent land to a depth of 500mm approx. The annual maintenance charge is expected to be £4,000. This cost does **not** include for land purchase and compensation costs. Optimism bias is not included in the figure above and if assumed to be at 60% will raise the total cost to £1,440,000.

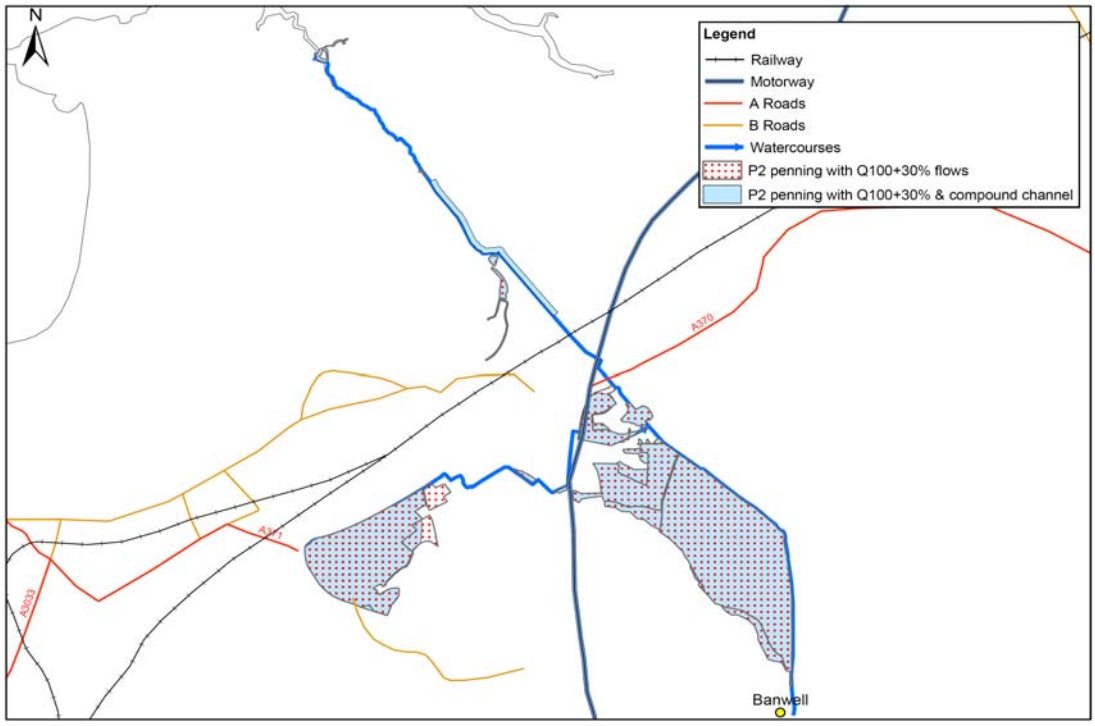
5.3.6 Should the disposal of material off site be necessary, landfill charges are expected to be in excess of £1.9m. This cost may be reduced through the use of more sustainable options such as the recycling of waste material for building works in the local vicinity as suggested in the costing given above (however the material is still subject to tax) or potential on-site disposal. A more detailed cost breakdown can be found in Appendix E.

Properties at risk

5.3.7 The preferred option seeks to reduce the potential risk of flooding in the St Georges area of Weston-super-Mare where the freeboard is compromised by increased flows due to development. There are still 14 properties at risk from potential flooding following extent mapping from the model results of this option. These are largely isolated properties and farms in the Banwell Moor area that are too sparsely located to make a defence scheme viable with or without Defra grant aid funding. Whilst the number of properties at risk has not changed been alleviated by this preferred option the potential flood risk through compromise to the current freeboard, has been reduced.

5.3.8 We would recommend that individual property based mitigation schemes are adopted and property owners encouraged to take up these measures through awareness schemes and financial assistance where possible. The flood extents taking account of this option are given in figure 5.8 below with more detail provided in drawing AA_0451 in Appendix A.

Figure 5.8
Banwell catchment: Flood extents after modelling compound channel with post development (P2) flows



5.4 Use of Sustainable Drainage Systems (SUDs)

5.4.1 SUDs should be used in addition to the flood risk mitigation measures outlined as preferred options in this section. Reference should also be made to guidance published by the Environment Agency and by the Construction Industry Research and Information Association (CIRIA) as well as any guidance set out by North Somerset Council.

5.4.2 A key requirement of PPS25 is the adoption and use of SUDs schemes in order to facilitate and promote sustainable patterns of development whilst avoiding flood risk and accommodating the impacts of climate change through positive planning. The effective disposal of increased surface water from development is much more effective when managed early in the land acquisition and design process of a new development rather than to resolve problems after development. SUDs cover the whole range of sustainable approaches to surface water management including:

- source control measures; such as rainwater recycling and drainage
- infiltration devices to allow water to soak into the ground; these can include individual soakaways and communal facilities

- filter strips and swales, which are vegetated features that hold and drain water downhill mimicking natural drainage patterns

- filter drains and porous pavements to allow rainwater and run-off to infiltrate into permeable material below ground and provide storage if needed

- basins and ponds to hold excess water after rain and allow controlled discharge that avoids flooding.

6 CONTRIBUTIONS

6.1.1 There are a number of capital options that have the capacity to improve the current flood risk situation as well as allowing additional development within the catchment. Following the River Banwell Pre-feasibility and Uphill Great Rhyne Pre-feasibility reports (Royal Haskoning 2006), the identification of new 100 year flood extents and the recent increase in the Defra priority score, it is unlikely that grant aid assistance will be available to improve the current flood risk under the Flood and Coastal Defence Project Appraisal Guidance (FCDPAG3) process.

6.1.2 Following the requirements of PPS25 all future development has to ensure that flood risk is not increased in the development or elsewhere within the catchment. Should large scale development be planned, The Partnership have the opportunity to request contributions from developers to allow the implementation of a comprehensive and consistent flood defence scheme that not only meets the requirements of PPS25 for the specific development but also improves the current flood risk throughout the catchment.

6.1.3 It is envisaged that payment for flood mitigation schemes will be identified through the creation of a formal consortium comprising key developers, representatives from NSC the EA and WMIDB. This consortium would have the ability to acquire land and borrow money in order to address flood mitigation measures. This would eliminate division over payments to deliver continuity and ensure equality amongst contributing parties.

6.2 Mechanism for contributions

6.2.1 The identification of a decision making process with regards to allocating contributions for flood risk mitigation works is still being developed by NSC for individual developers. We have therefore provided general proposed developer conditions for the key development sites for the Weston Development Areas as set out in section 2.3 figure 2.3 as opposed to individual developer sites.

6.2.2 The Partnership is required to ascertain what amenity and recreation improvements with regard to flood risk are required. The mechanism and calculation of contribution costs needs to be agreed in the near future so that the process is transparent from the initial stages.

6.2.3 Royal Haskoning suggest that contributions are made based on an assessment of the percentage of development land within the Weston Development Area as a whole, with the application of a weighting factor concerning land allocations to incorporate the market value elements of roof tax. Allowances then need to be made for the loss of floodplain due to development and the mitigation effects of on site storage and SUDs schemes. These should not compromise the overall requirements of the Partnership with regard to amenity and recreational provision. This suggested staged approach is set out in table 6.1.

6.2.4 In order to make a consistent and unbiased assessment of hydraulic flows, the project team have made a requirement to retain Royal Haskoning as custodians of the Weston Flood Management study models to aid the Partnership with the interpretation of hydrological results from developers submitting applications within the Weston Development Area. This will assist with the overall requirements of the vision, the EA and the WMIDB whilst preventing mis-interpretation and incompatible results. It is envisage that a number of regulations, terms and conditions will be drawn up to provide a thorough agreement on this preferred methodology.

Table 6.1
Suggested contributions mechanism

Task		Detail
1	Cost	Uphill plus Banwell options minus existing funds and government/EA funding
2	Partnership Decision Making	Identify requirements of balance for flood risk, amenity and recreation provision. Need to stipulate this to prevent 100% on site mitigation measures and therefore no added value benefits.
3	Hydraulic Requirements	Identify the minimum run off volume required to achieve the minimum lake size (for Uphill catchment). Assess the contribution level from each site by calculating the percentage of each development site within the Weston Development Area as a whole. Assess how much of the remaining flow will be attenuated on site by using information from the post development flows hydrograph.
4	Roof Tax	For each development calculate the area of each land allocation and then present it as a ration of land allocation types for the area as a whole. Assign a weighting for market values.
5	Loss of floodplain	Calculate how much floodplain lost for specific sites as ratio of floodplain across whole development area. Recommend that contributions from these sites should be higher
6	Calculation of Contribution Costs	Calculate using contribution calculator spreadsheet.
7	Additional payment to WMIDB	Commuted sums for future maintenance

7 PROPOSED DEVELOPER CONDITIONS

7.1 Overview

7.1.1 The conditions set out in this section are to facilitate the development of flood risk mitigation measures in a holistic and integrated way whilst allowing provision for the aspirations and concepts of the Weston Vision. Section 7.1 provides conditions that are generic to the development area as a whole whereas section 7.2 covers conditions specific to the following 5 key development areas:

- RAF Locking
- West Wick and Worle
- Town Centre Gateway (southern area)
- Airfield Neighbourhoods
- Rhynes Neighbourhoods

7.1.2 Appendix G also contains information to help guide the planning authority in making judgements on allocating land for potential development through the planning process and under the guidelines of PPS25. It also informs the preparation of strategic policy and development control policies towards flooding and flood risk which can then be included in the Local Development Framework. The information may also be used as evidence for informing planning policy and development control decisions. It should be noted that this report does not remove the requirement for site specific Flood Risk Assessments (FRAs). Specific guidance relating to the implementation of FRAs and also the benefits of SUDs schemes can also be found in Appendix G.

7.2 Conditions for the Development area as a whole

7.2.1 Conditions from a number of sources have been identified including the West Mendip Internal Drainage Board, North Somerset Council, and The Environment Agency and from the guidance in PPS25: Development and Flood Risk.

North Somerset Council

7.2.2 Further planning conditions may be required by NSC in accordance with Planning Policy for the development area.

Environment Agency

7.2.3 Conditions imposed by the EA would need to cover the following

- Detailed design
- Implementation and phasing
- Future use and operation of the facilities
- Access and maintenance
- Depending on who managed the infrastructure - commuted sum payments
- Operation and Maintenance manual

No development approved by this permission shall be commenced until a scheme for the provision of flood mitigation and surface water drainage works has been submitted to and approved in writing by the Local Planning Authority. The implementation shall be completed in accordance with the approved programme and details.
Reason: To mitigate the risk of flooding to the development and third parties

No development approved by this permission shall be occupied until an Operation and Maintenance manual has been submitted to and approved in writing by the Local Planning Authority. The Manual shall also contain a full set of 'as constructed drawings'
Reason: To ensure the satisfactory operation and maintenance of the flood mitigation and surface water attenuation facilities

West Mendip Internal Drainage Board

7.2.4 The WMIDB has confirmed its agreement to and support for the developing flood risk management strategy, and for the concept of retaining existing watercourses where development layouts so allow and/or providing new watercourses, for the storage and conveyance of surface water runoff. The Board firmly believes that all such watercourses should be vested on the Board, as the operating authority and would therefore be maintained by the Board. The Board is also in principle prepared to maintain 'wet' flood storage areas and balancing lakes set in public open space.

7.2.5 Apart from drainage works that only affect the 'main river' system - Uphill Great Rhyne, Cross Rhyne downstream of Winterstoke Road or the River Banwell - all other drainage works will require the Internal Drainage Board's consent under the provisions of the Land Drainage Act 1991. In addition, the WMIDB has made Byelaws under Section 66 of the 1991 Act, to further control works and activities undertaken by third parties affecting watercourses within its Drainage District. In particular, these Byelaws permit the Board to control the rate of surface water run-off from development sites into the Drainage District.

7.2.6 To meet the requirements of the Act and the Byelaws, all developers proposing to undertake any works affecting watercourses within the West Mendip Internal Drainage District must submit details of their proposals to the Board. In considering an application for consent, the Board may request such modifications to the proposals which it considers necessary, in order to control flood risk in accordance with the agreed strategy for the catchment and to satisfy its environmental duties. Riparian owners, developers, and all other persons proposing to carry out any works affecting a watercourse must, therefore, obtain Land Drainage Consent from the Board before commencing work on site.

7.2.7 The design standards for all new flood protection works must be in accordance with the flood risk management strategy agreed between North Somerset Council, the Environment Agency and the Internal Drainage Board. Hydraulic modelling of all new flood protection works must be verified against the 'master catchment models' held by Royal Haskoning, on behalf of the authorities. Internal Drainage Boards have a duty to conserve, enhance and protect the natural environment. The West Mendip Internal Drainage Board will, therefore, consider the nature conservation implications of any proposal, when determining a Land Drainage Consent Application.

7.2.8 In granting consent under the Land Drainage Act 1991 for new and improved watercourses, flood storage areas and all associated structures, the Board would seek to ensure the following basic requirements are met:

- Watercourses (or flood storage areas) to be 'vested' in the Board, as operating authority, for essential maintenance purposes with the land forming the watercourse (or flood storage area) including its bed and banks and the maintenance corridors on either side, conveyed to the local authority as public open space.

- All culverts shall, unless otherwise approved by the Board's Engineer, be of 1200mm minimum diameter and culverts constructed to cross under adopted highways, footpaths and cycle ways shall be adopted by the highway authority as 'highway structures'. Sizes are to be confirmed through integration into the master model.

- The Board's Land Drainage Byelaws shall apply to all such watercourses and flood storage areas.

- Primary maintenance corridors on 'working banks' and used by operating plan and associated equipment shall be a minimum of 6 metres unobstructed width and, where required, access gates shall be of 4 metres minimum clear opening width.

- Secondary maintenance corridors on 'non-working banks' shall be a minimum of 4 metres unobstructed width, unless conservation and/or other environmental requirements need to take precedence in specific cases.

- Primary maintenance corridors shall not be constructed with a cross fall exceeding 2% without the specific approval of the Board's Engineer.

- Payment shall be made to the Board of a dedicated commuted sum to cover future watercourse maintenance costs, in accordance with the principles for managing residual flood risk, as set out in PPS25. Such sums to be determined for each individual development site; based on the length and location of on-site open watercourses and flood storage areas, the length and size of culverts constructed, and the area of impermeable surface connected to the watercourse system.

- The developer shall meet the Board's reasonable costs associated with the technical examination of proposals submitted for Land Drainage Consent and for the engineering inspection of such works on site.

7.2.9 The Government aims to reduce the risk from flooding to people and the developed and natural environment by discouraging development within areas at medium to high risk of flooding. Government guidance has been produced for local planning authorities to help them when allocating land for development in order to meet this aim. Following the publication of PPS25 on 7th December 2006 (which replaces PPG25) the following key statements have been included. Those proposing development are responsible for:

- demonstrating that it is consistent with the policies in PPS25 and those on flood risk in the Local Development Documents
- providing a FRA demonstrating whether any proposed development is likely to be affected by current or future flooding from any source, satisfying the LPA that the development is safe and where possible reduces flood risk overall, whether it will increase flood risk elsewhere and the measures proposed to deal with these effects and risks and any necessary flood risk management measures should be sufficiently funded to ensure that the site can be developed and occupied safely throughout its proposed lifetime. Planning applications for development proposals of 1 hectare or greater in Flood Zone 1 and all proposals for new development located in Flood Zones 2 and 3 should be accompanied by a FRA.
- This report can provide background data for the preparation of a FRA.
- Follow designs which reduce flood risk to the development and elsewhere, by incorporating sustainable drainage systems and where necessary, flood resilience measures
- Identify opportunities to reduce flood risk, enhance biodiversity and amenity, protect the historic environment and seek collective solutions to managing flood risk.

7.3 Conditions for the five key Development areas

7.3.1 The preferred scheme for development comprises an amalgamation of a number of different mitigation measures and will include details for on site mitigation works, finished flood levels and off site mitigation works. The recommended works for all 5 key sites are summarised in table 7.1.

Off site mitigation works

7.3.2 The scale and extent of these works is largely dependent on the requirements of the Partnership and the aspirations of the Weston Vision and the determination of the minimum and maximum run off volumes required from each development site.

7.3.3 For the Banwell catchment, there is no advantage to be gained in providing a staged construction approach for the creation of the compound channel and raised embankments (in part) and all works can be carried out as one project.

7.3.4 For the Uphill catchment which covers the majority of the development areas, the airfield culvert can be built as Phase 1 works followed by Phase 2 works to include the construction of new channels, the tilting weir and outlet control structure to control flows. The lake itself can be constructed as a continuing phased project over time with the available storage volume increasing as development progresses across the Weston Development Area as a whole. This will allow for continued assessment of the effects of development on increased run off, potential flood risk, possible alterations to the size of the lake required to meet future flood risk mitigation needs and amenity and recreation provision.

On site mitigation works

7.3.5 The scale and extent of these works is largely dependent on the requirements of the Partnership and the aspirations of the Weston Vision. This study set out to prove that off site mitigation can attenuate significant volumes, however on site mitigation has a vital role to play. In the preferred option for the Uphill catchment, the 1300mm former airfield culvert has been opened up to provide a two stage channel with a volume of 11250m$^{3.}$ No other specific on site works have been formally identified through the options presented but SUDs schemes and other mitigation measures should be considered to attenuate above minimum flow volumes as required by the Weston Vision aspirations.

Floor Levels

7.3.6 The recommended finished floor levels as derived from the hydraulic model are set out in Table 7.2a below and assume a freeboard of 600mm. They assume a 20% increase in flows due to climate change as outlined in PPS25 and a 10% precautionary allowance. Developers should also seek to adhere to guidelines for flood resilient and resistant buildings and construction designed to reduce the consequences of flooding and facilitate recovery from the effects of flooding sooner than conventional buildings.

7.3.7 This may be achieved through the use of water-resistant materials for floors, walls and fixtures and the siting of electrical controls, cables and appliances at a higher than normal level. If the lowest floor level is raised above the predicted flood level, consideration must be given to providing access for those with restricted mobility. Consideration of appropriate resilience measures requires the undertaking of an FRA to provide a clear understanding of the mechanisms that lead to flooding and the nature of the flood risk. Guidance on the resilient construction of buildings is being prepared to support any further requirements of the Building Regulations. It will be available from the Communities and Local Government Planning Portal websites www.communities.gov.uk or www.planningportal.gov.uk.

Timing of mitigation works

7.3.8 The flowchart in figure 7.1 represents the three stages of work required and the relative timings of each. For certain works a phased approach can be adopted to allow for development expansion over time.

Figure 7.1
Timing of mitigation works

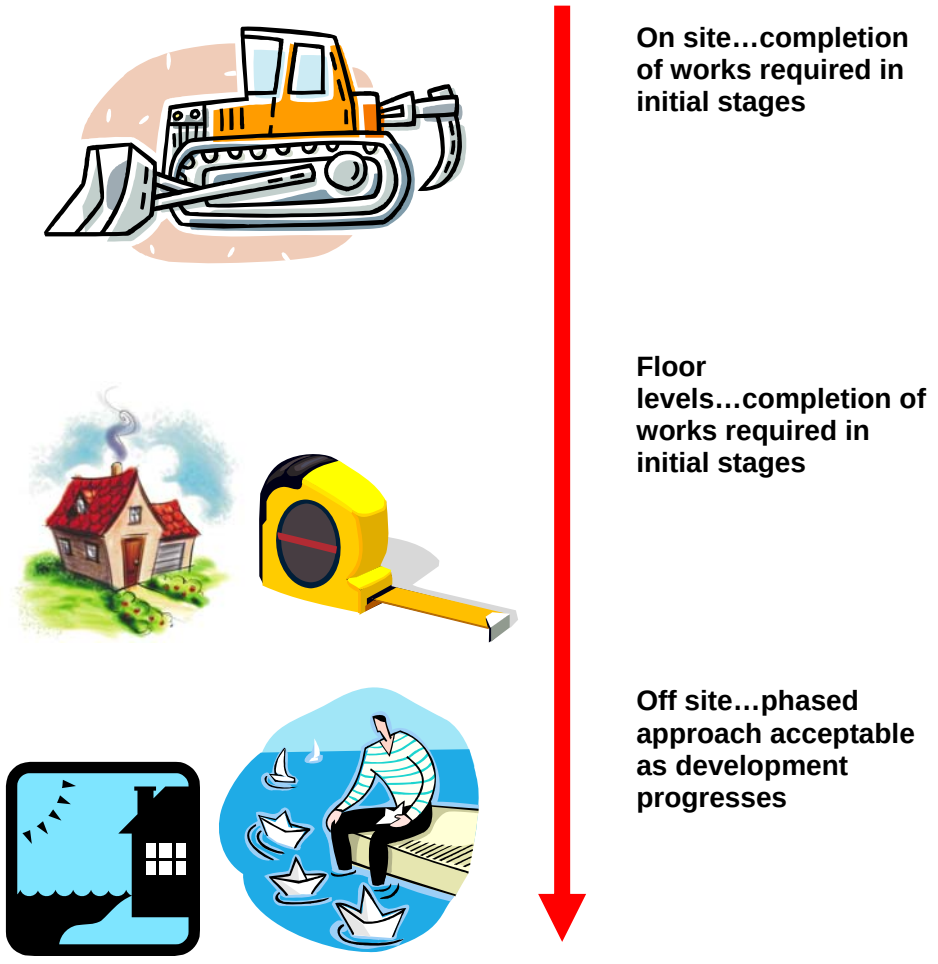


Table 7.1: Conditions for key Development Areas

Dment Area	% of WDA	On site works	Floor levels (includes 600mm freeboard)			Off site works
			Q100+30% pre-development levels	Q100+30% post development levels	Q100+30% with preferred option (online lake)	
RAF Locking	16.1%	Use of SUDs and attenuation measures possible once minimum run-off requirement fulfilled.	5.43-5.64mAOD	5.56-5.71mAOD	5.48-5.61mAOD	Diverted Cross Rhyne flows, online lake and wetland storage areas with control structures. Compound channel to provide additional protection to St. George's area due to increased levels compromising freeboard.
West Wick and Worle	12.5%	Use of SUDs and attenuation measures possible once minimum run-off requirement fulfilled.	4.5-4.98mAOD	4.5-4.99mAOD	4.5-4.62mAOD	Diverted Cross Rhyne flows, online lake and wetland storage areas with control structures.
Town Centre Gateway (southern area)	20.5%	Use of SUDs and attenuation measures possible once minimum run-off requirement fulfilled.	5.79mAOD	5.85mAOD	5.79mAOD	Diverted Cross Rhyne flows, online lake and wetland storage areas with control structures.
Airfield Neighbour-hoods	23.7%	Opening up of airfield culvert to provide additional storage and green corridor access. Use of SUDs and attenuation measures possible once minimum run-off requirement fulfilled.	5.54mAOD	5.70mAOD	4.85-5.03mAOD	Diverted Cross Rhyne flows, online lake and wetland storage areas with control structures.
Rhynes Neighbour-hoods	16.1%	Use of SUDs and attenuation measures possible once minimum run-off requirement fulfilled.	5.64mAOD	5.71mAOD	5.48mAOD	Diverted Cross Rhyne flows, online lake and wetland storage areas with control structures.

8 CONCLUSIONS AND RECOMMENDATIONS

General

8.1 There are a number of capital options that have the capacity to improve the current flood risk situation as well as allow additional development within the catchment.

8.2 All future development will have to comply with the requirements of PPS25 to ensure that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas of flooding, and to direct development away from areas at highest risk. Where new development is necessary in such areas, policy aims to make it safe without increasing flood risk elsewhere and where possible, reducing flood risk overall. Should large scale development be planned, The Partnership have the opportunity to require contributions from developers to allow the implementation of a flood defence scheme that not only meets the requirements of PPS25 for the specific development but also improves the current flood risk throughout the catchment.

8.3 A number of requirements and conditions for developers have been identified by the West Mendip Internal Drainage Board, North Somerset Council and the Environment Agency and are outlined in section 7. These must be adhered to and it is the responsibility of the planning authority to ensure that this is the case.

8.4 Both this Options Report and the Strategic Flood Risk Assessment (SFRA) are likely to be adopted as Supplementary Planning Documents (SPD) which will then undergo a consultation process.

8.5 NSC and the EA have requested to retain Royal Haskoning as custodians of the Weston Flood Management study models to facilitate the Partnership with the interpretation of hydrological results from developers submitting applications within the Weston Development Area. This will assist with the overall requirements of the Vision and the requirements of the EA and the WMIDB. It will also aim to prevent mis-interpretation and incompatible results. A statement of use, and a number of ‘rules’ will be developed, to ensure that any assessment carried out is consistent and unbiased for all parties. This will also include a fee structure. NSC and the EA will retain the Intellectual Property Rights for the use of the model.

8.6 A development from this study will be the production of updated Flood Zone 3 maps showing the extent of fluvial flooding at the 0.1% probability level. This work will be carried out as a separate commission for the Environment Agency and is expected to be completed during 2007. Following the release of these extents, the SFRA will then be updated and will also incorporate the new tidal extents (0.5% probability) information from the North Wessex Tidal Flood Zone Compliance and Areas Benefiting from Defences (ABD’s) Main Stage (Royal Haskoning, ongoing).

8.7 Further work will need to be carried out by NSC to identify and develop a contribution methodology to assess how an un-biased and fair financial contributions mechanism will operate. This is likely to lead to a further Phase III study for the Weston Flood Management Study.

8.8 Following the River Corridor Survey, Extended Phase 1 Habitat Survey and Water Quality survey there are no species of significant conservation interest encountered during the survey and habitats noted within the survey (on the Banwell catchment) are of local conservation interest only. Water quality is poor particularly within the Uphill catchment.

Uphill catchment

8.9 The proposed development would significantly increase flood risk in the Uphill catchment

8.10 There is a possibility that additional surface water flows currently discharging through the Uphill Great Rhyne catchment as sewer flows may be re-routed in part into the rhyne system. It is expected that Wessex Water will be able to provide an assessment of expected flows for the 100 year return period by spring 2007 and an additional hydraulic study may be commissioned to identify the effect this will have on the catchments as a whole. Should it be necessary, Wessex Water could become part of the contribution consortium and provide financial input as required. Following adoption of the preferred option there would be some additional capacity in the Uphill Great Rhyne catchment due to the diversion of Cross Rhyne flows, which may be sufficient to mitigate additional surface water or the concept of cross catchment flows could be further developed.

8.11 The preferred option for Uphill Great Rhyne and Cross Rhyne is Option 10-Diverted Cross Rhyne with online lake and wetland areas and culvert works. The combination of re-routing Cross Rhyne and providing additional storage through the creation of a lake and two stage channel in the location of the former airfield culvert provides sufficient attenuation and also reduces levels within the upstream reaches of Uphill Great Rhyne. Future development therefore takes account of PPS25 policy. The potential risk of flooding is reduced from 188 to 4 properties.

8.12 Following detailed hydraulic modelling it is observed that the development area known as Neighbourhood Rhynes is prone to flooding for both the Banwell and Uphill Great Rhyne catchments. It was also permitted to accommodate excess flows from Moorland Drove Rhyne (which drains the Moor Lane area) through the provision of a number of spillways along this rhyne. This area is marked for the final stages of development as part of the Weston Development Area. We would recommend that some formalised storage is provided and with further assessments as to the location and volume of storage required, to be carried out as surrounding development progresses.

8.13 The effect of cross catchment flows was assessed in order to potentially reduce the impact of increased surface water flows due to development on the Uphill Great Rhyne watercourse system. At this stage of development we do not believe that any diversion of flows would be viable. However the development of the Rhynes Neighbourhood area may lead to a sufficient increase in flows to warrant the development of a new route (through either motorway culvert). We recommend that this is further investigated as this stage of development approaches.

Banwell catchment

8.14 The proposed development would have little impact on flood risk in the Banwell catchment.

8.15 The preferred option for Preferred Option for River Banwell, Moorland Drove, West Wick and Way Wick Rhyne is Option 11: Compound Channel. This smaller scale option is more appropriate to mitigating against the increased level of flood risk and takes account of PPS25 policy. Whilst the number of properties at risk is not reduced, the freeboard adjacent to the St Georges area is within the Environment Agency's recommended level.

8.16 This study has identified that the requirement to provide formalised storage within the Banwell catchment is not economically justifiable on flood risk grounds alone. There is however an opportunity for environmental improvement and the enhancement of biodiversity within this area and we recommend that this be explored further, possibly through the commission of a separate study in association with an environment body.

Appendix A

Flood Extent Plans

Appendix B

Options Plans

Appendix C

Modelling Report for Uphill catchment

Appendix D

Modelling Report for Banwell catchment

Appendix E

Options Evaluation

Appendix E

Evaluation of Options

Table 5.1 summarises the potential effects of each option on flood risk and the impacts on environment, human environment and economics factors and any associated opportunities and constraints. This is to provide a summary of the benefits and restrictions of each option and provide an account of the reasoning used to identify the preferred option/s for each catchment area. . Those options that have been taken forward are shaded in green.

Table 5.1
Evaluation of options

Option	Flood Risk elements	Environmental Factors	Human Environment Factors	Economic Factors
Uphill Great Rhyne and Cross Rhyne				
1.Do Nothing	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.			
	Potential increases in flooding extent, frequency and depth and therefore flood risk are not being addressed.	Increase in river continuity could benefit sediment transport, migration of aquatic species and reduce impoundment with potential benefits for water quality.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Increased flooding is likely to have a negative impact on local communities, agricultural production, infrastructure and archaeological sites.
	Cessation of operation, deterioration and failure of flow control structures	Morphological and ecological recovery of the watercourse could occur. However, without active intervention and management, low stream power may limit the potential for recovery missing the opportunity to restore fluvial functionality.	Deterioration and failure of existing structures could cause negative impact on the visual amenity of the watercourse which forms an integral part of the catchment and landscape.	Flows available for agricultural purposes reduced during summer months

	Ingress of tidal waters as Uphill sluice not operated	Downstream areas will take on brackish characteristics, restoring an element of habitat functionality but potentially causing a negative impact on freshwater fauna and flora.		Increased flooding is likely to have a negative impact on local communities, agricultural production, infrastructure and archaeological sites.
	Increased growth of vegetation as not cut due to cessation of bank maintenance.	Potential improvement in riparian and marginal habitats and potential interception of agricultural diffuse pollutants . Attenuation of fluvial flows upstream could help decrease conveyance and flooding downstream.	Restricted access to the watercourse for recreational purposes	Cost savings due to lack of operation and maintenance.

2.Do Minimum/Existing	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. No major environmental constraints have been identified though environmental enhancement is recommended. Development would be allowed contrary to PPS25 policy.			
	Potential increases in flooding extent, frequency and depth and therefore flood risk are not being addressed.	An increase in river continuity could benefit sediment transport, migration of aquatic species and reduce impoundment with potential benefits for water quality.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Increased flooding is likely to have a negative impact on local communities, agricultural production, infrastructure and archaeological sites.
	Continuation of existing maintenance regimes	Limited opportunity for landscape and environmental enhancement to meet BAP	Continuation of existing maintenance regimes	Opportunity to review more efficient maintenance schemes could be taken.

		targets under current conditions. Increased opportunity for clearance of debris and fly tipped material. Opportunity missed to restore fluvial functionality.		

3.Flood Warning	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. The hydrograph peak due to increased surface water runoff does not have sufficient lag time to allow operation of a flood warning system. Flood mitigation measures will need to be implemented. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.			
	Potential increases in flooding extent, frequency and depth and therefore flood risk are not being addressed.	Increase in river continuity could benefit sediment transport, migration of aquatic species and reduce impoundment with potential benefits for water quality.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Increased flooding is likely to have a negative impact on local communities, agricultural production, infrastructure and archaeological sites.
	Reduction in the level of consequence of flooding		Increased awareness of flood risk may have a beneficial impact on local communities, agricultural production and infrastructure as damages are reduced.	Increased awareness of flood risk may have a beneficial impact on local communities, agricultural production and infrastructure as damages are reduced.
	No direct impact on existing maintenance regimes	Opportunity missed to enhance or improve watercourse network.	No direct impact on existing maintenance regimes	

4.Flood	This option is not viable due to other flood mitigation options having a more beneficial effect on the reduction of water levels.

Banks/Walls	There are potential problems with accessibility, maintenance and cost particularly along reaches of the Uphill Great Rhyne. The length of walls required is not as extensive as first envisaged following analysis of the pre and post development water levels. The upstream benefit provided is not sufficient. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.			
	Decrease of flood extent, frequency and depth to incorporate greater volumes of surface runoff.		Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Bank/wall construction	Further disconnects the channel system from its floodplain and reduces interaction which may increase siltation as reduced transfer of sediment to the floodplain during high flow events and detract from habitat value of channels. Potential for increased point source pollution from drainage points.	Creates a barrier between the community, channels and their floodplains. Visual amenity may be improved through planting and landscaping.	Cost of construction will be low.
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

5a.Flood Storage (via channel amalgamation)	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.

	Decrease or maintenance of flood extent, frequency and depth to incorporate greater volumes of surface runoff.	Reduction in flooding over existing areas could reduce sediment transfer to the floodplain and reduce habitat quality of existing floodplain areas	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Widening of existing rhynes	Potential low flow conditions leading to issues with siltation and water quality. Creation of greater in-channel capacity rather than floodplain storage therefore opportunities for increasing floodplain connectivity and creation of wetland habitats limited.	Existing public access to be maintained. Visual amenity may be improved through planting and landscaping.	
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

5b.Flood Storage (as in 5a) plus recreation lake and wetland area	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. Development would be allowed contrary to PPS25 policy. The concept of this option has been developed further into option 10 The location of the lake does not attenuate sufficient flows in order to reduce the flood risk in the upstream reach of Uphill Great Rhyne. No major environmental constraints have been identified.			
	Increase in flood storage capacity due to creation of lake.	Potential for environmental enhancement and habitat creation.	Opportunity to provide recreational and educational benefit, reconnecting the community with the watercourse	Loss of grazing land and other agricultural usage.

			systems.	
	Reduction of peak flow through lower reaches of the rhynes.	Potential reduction of flushing of fine sediment through the river during high flow events.		Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Occasional / seasonal inundation of open spaces	Wetland creation opportunities providing ecological and landscape benefit.	Temporary loss of use of open spaces. Wetland creation opportunities providing recreational and educational benefits.	
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

6.Culvert Works and Flood Storage (as in 5a)	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. Development would be allowed contrary to PPS25 policy. No major environmental constraints have been identified.			
	Opening up of culvert	Potential to incorporate river habitat and wetland enhancements along the new watercourse.	Less sustainable than floodplain creation. Provision of associated recreational and educational benefit.	
	Potential changes to flows	Potential changes in water quality and possible disturbance of potentially contaminated land (given the sites former use)	Perceived increase in flood risk by local community	
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels,	Temporary impact on recreation and negative impact on	

		water quality, flora and fauna.	traditional landscape character.	

7.Pumping Station, Culvert Works and Flood Storage (as in 5a)	This option has not been followed as the storage capacity available is not making a significant impact on water levels. It provides limited additional storage capacity and reduces maintenance costs whilst allowing for environmental enhancement. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy. This option is against the aspirations of the Weston Development Area due to unsustainability (from Pumping Station), costs and associated maintenance.			
	Installation of pumping station	Pumping is fundamentally unsustainable as a solution; it would be preferable to design a self-regulating system.		High cost of installation and maintenance
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

8.Sustainable Drainage Systems (SUDs)	All development should adhere to North Somerset Councils central SUDs policy. Contributions to flood risk mitigation measure should make allowances for minimising run off and on site attenuation. No major environmental constraints have been identified. Development takes account of PPS25 policy.			
	Increased attenuation of urban flows	Potential reduction in fine sediment and other diffuse pollutants leading to possible increased water quality.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Opportunity for design	Opportunities for habitat creation dependent upon design and function.	Opportunity to provide recreational and educational benefit.	

			Visual amenity may be improved	
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

9. Flood Storage (as in 5b) and flood banks/walls (as in 4)	This option has been developed and superseded by Option 10, which costs less and potentially reduces water quality issues to the proposed lake.

10. Diverted Cross Rhyne with online lake, wetland area and culvert works	The combination of re-routing Cross Rhyne and providing additional storage through the creation of a lake and two stage channel in the location of the former airfield culvert provides sufficient attenuation and also reduces levels within the upstream reaches of UGR. No major environmental constraints have been identified. Development takes account of PPS25 policy.			
	Increase in flood storage capacity due to creation of lake.	Potential for environmental enhancement and habitat creation.	Opportunity to provide recreational and educational benefit, reconnecting the community with the watercourse systems.	Loss of grazing land and other agricultural usage.
	Reduction of peak flow through other reaches of the rhynes.	Potential reduction of flushing of fine sediment through the river during high flow events.		Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Occasional / seasonal inundation of open spaces	Wetland creation opportunities providing ecological and landscape benefit.	Temporary loss of use of open spaces. Wetland creation opportunities providing recreational and educational benefits.	
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels,	Temporary impact on recreation and negative impact on	Relatively high cost.

		water quality, flora and fauna.	traditional landscape character.	

Option	Flood Risk elements	Environmental Factors	Human Environment Factors	Economic Factors
River Banwell, Moorland Drove, West Wick and Way Wick Rhyne				
1.Do Nothing	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy though the increased flood risk due to development is small in this area.			
	Potential increases in flooding extent, frequency and depth and therefore flood risk are not being addressed.	Increase in river continuity could benefit sediment transport, migration of aquatic species and reduce impoundment with potential benefits for water quality.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Increased flooding is likely to have a negative impact on local communities, agricultural production, infrastructure and archaeological sites.
	Cessation of operation, deterioration and failure of flow control structures	Morphological and ecological recovery of the watercourse could occur. However, without active intervention and management low stream power may limit the potential for recovery missing the opportunity to restore fluvial functionality.	Deterioration and failure of existing structures could cause negative impact on the visual amenity of the watercourse which forms an integral part of the catchment and landscape.	Flows available for agricultural purposes reduced during summer months
	Ingress of tidal waters as Uphill sluice not operated	Downstream areas will take on brackish characteristics, restoring an element of habitat functionality but potentially		Increased flooding is likely to have a negative impact on local communities, agricultural production, infrastructure and

		causing a negative impact on freshwater fauna and flora.		archaeological sites.
	Increased growth of vegetation as not cut due to cessation of bank maintenance.	Potential improvement in riparian and marginal habitats and potential interception of agricultural diffuse pollutants . Attenuation of fluvial flows upstream could help decrease conveyance and flooding downstream.	Restricted access to the watercourse for recreational purposes	Cost savings due to lack of operation and maintenance.

2.Do Minimum/Existing	This option has been followed across the majority of the Banwell catchment as the increased flood risk due to development is minimal in this area. No major environmental constraints have been identified though environmental enhancement is recommended. The risk is still evident but there are not sufficient properties to make it economically viable to develop a protection scheme for this area.			
	Potential increases in flooding extent, frequency and depth and therefore flood risk are not being addressed.	An increase in river continuity could benefit sediment transport, migration of aquatic species and reduce impoundment with potential benefits for water quality.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Increased flooding is likely to have a negative impact on local communities, agricultural production, infrastructure and archaeological sites.
	Continuation of existing maintenance regimes	Limited opportunity for landscape and environmental enhancement to meet BAP targets under current conditions. Increased opportunity for clearance of debris and fly tipped material. Opportunity missed to restore fluvial functionality.	Public perception of watercourse system as a resource would not greatly improve. Maintenance of existing access.	Opportunity to review more efficient maintenance schemes could be taken.

3.Flood Warning	This option is against the aspirations of the Weston Development Area and does not address the current flood risk or any increased risk due to development. Individual property protection is recommended via a programme of awareness and possible financial incentives. Flood mitigation measures will need to be implemented. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.			
	Reduction in the level of consequence of flooding		Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25) Benefit to local communities in managing flood risk	Increased awareness of flood risk may have a beneficial impact on local communities, agricultural production and infrastructure as damages are reduced.
	No direct impact on existing maintenance regimes	Opportunity missed to enhance or improve watercourse network.		

4.Flood Banks/Walls	This option has been followed in part in the St Georges area just north of the M5 as there are several low points along the existing banks. The length of additional embankment required is not as extensive as first envisaged following analysis of the pre and post development water levels. No major environmental constraints have been identified.			
	Decrease or maintenance of flood extent, frequency and depth to incorporate greater volumes of surface runoff.		Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Bank/wall construction	Further disconnects the channel system from its floodplain and reduces interaction which may	Creates a barrier between the community, channels and their floodplains.	Cost of construction will be low.

		increase siltation as reduced transfer of sediment to the floodplain during high flow events and detract from habitat value of channels. Potential for increased point source pollution from drainage points.	Visual amenity may be improved through planting and landscaping.	
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

5a. Flood Storage (Banwell Moor)	The location of the storage area does not have an impact on reducing increased flood risk. Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.			
	Decrease or maintenance of flood extent, frequency and depth to incorporate greater volumes of surface runoff.	Reduction in flooding over existing areas could reduce sediment transfer to the floodplain and reduce habitat quality of existing floodplain areas	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Increase in flood storage capacity due to creation of defined area.	Increased floodplain connectivity, with increased resultant sediment deposition onto floodplain.	Opportunity to provide recreational and educational benefit, reconnecting the community with the watercourse systems.	Loss of grazing land and other agricultural usage.
	Reduction of peak flow through lower reaches of the	Potential reduction of flushing of fine sediment through the river		Decreased flooding may have a beneficial impact on local

	River Banwell.	during high flow events.		communities, agricultural production and infrastructure
	Occasional / seasonal inundation of open spaces	Opportunities for targeted habitat creation (UKBAP habitats *e.g.* grazing marsh) providing ecological and landscape benefit. Potential spread of pollutants onto the floodplain.	Temporary loss of use of open spaces Wetland creation opportunities providing recreational and educational benefits.	Temporary loss of agricultural usage of Banwell Moor
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation.	

5b. Flood Storage (Banwell Moor) (as in 5a) and Flood Banks/Walls (as in 4)	The location of the storage area does not have an impact on reducing increased flood risk. Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.

6a.Flood Storage (Banwell Moor and New Bow) (as in 5a)	The location of the storage area does not have an impact on reducing increased flood risk. Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.

6b.Flood Storage (Banwell Moor and New Bow) and Flood Banks	The location of the storage area does not have an impact on reducing increased flood risk. Environmental enhancement is recommended through formalisation of storage to increase biodiversity levels i.e. wetland creation. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.

(as in 5b)	

7.Channel Widening	The flood defence benefit is not deemed sufficient to make this option viable on the grounds of flood risk, economic factors (disposal of excavated material) and environmental factors (maximum impact and potential low flow issues). No major environmental constraints have been identified.			
	Decrease or maintenance of flood extent, frequency and depth to incorporate greater volumes of surface runoff.	Reduction in flooding over existing areas could reduce sediment transfer to the floodplain and reduce habitat quality of existing floodplain areas	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Widening of existing rhynes and increased channel capacity	Opportunities for targeted habitat creation (UKBAP habitats *e.g.* grazing marsh) but also loss of existing habitats. Potential for low flow conditions leading to issues with siltation and water quality.	Existing public access to be maintained. Visual amenity may be improved through planting and landscaping.	Cost of construction and disposal of material likely to be high.
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

8.Pumping Station, Storage (as 6a) and Flood Banks (as 4)	This option is against the aspirations of the Weston Development Area due to unsustainability (from Pumping Station), costs and associated maintenance. No major environmental constraints have been identified. Development would be allowed contrary to PPS25 policy.			
	Installation of pumping station	Pumping is fundamentally unsustainable as a solution; it		High initial capital costs and associated ongoing operation

		would be preferable to design a self-regulating system.		and maintenance costs.
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

9.Diversion Channel	The flood defence benefit is not deemed sufficient to make this option viable on the grounds of flood risk, economic factors (disposal of excavated material) and environmental factors (maximum impact). No major environmental constraints have been identified.			
	Decrease in flood extent, frequency and depth to incorporate greater volumes of surface runoff.	Potential to reduce quality of existing niche habitats. Reduction in flooding over existing areas could reduce sediment transfer to the floodplain and reduce habitat quality of existing floodplain areas.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Creation of a new watercourse	Opportunities for targeted habitat creation and environmental enhancements within the channel and on the floodplain (UKBAP habitats *e.g.* grazing marsh. Potential spread of pollutants into the Congresbury Yeo catchment. Less sustainable than floodplain creation.	Opportunity to provide recreational and educational benefit	Potential loss or severance of agricultural fields. Cost of construction and disposal of material is high.
	Change in existing drainage	Opportunity to increase flow and		Increased flooding is likely to

	pattern with potential increased flood risk in adjacent catchment.	morphological diversity Decrease in river continuity further disrupting migration of aquatic species and downstream sediment transport.		have a negative impact on local communities, agricultural production, infrastructure and archaeological sites.
	Reduction of peak flows through lower reaches of the River Banwell.	Diversion channel must be designed in a manner which is environmentally sensitive to prevent deleterious effects occurring.	Potential reduction of flushing of fine sediment through the river during high flow events.	
	Disruption during construction of new watercourse	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation.	

10.Sustainable Drainage Systems (SUDs)	All development should adhere to North Somerset Councils central SUDs policy. Contributions to flood risk mitigation measure should make allowances for minimising run off and on site attenuation. No major environmental constraints have been identified. Development takes account of PPS25 policy.			
	Increased attenuation of urban flows	Potential reduction in fine sediment and other diffuse pollutants leading to possible increased water quality.	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Opportunity for design	Opportunities for habitat creation dependent upon design and function.	Opportunity to provide recreational and educational benefit. Visual amenity may be improved	
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels,	Temporary impact on recreation and negative impact on	

		water quality, flora and fauna.	traditional landscape character.	

11.Compound Channel	This smaller scale option is more appropriate to mitigating against the increased level of flood risk and provides fewer accessibility and maintenance issues compared to solely raising bank levels. It also is more cost effective (if the cost of the disposal of material is discounted). There is potential for significant environmental enhancements. No major environmental constraints have been identified. Development takes account of PPS25 policy.			
	Decrease in flood extent, frequency and depth to incorporate greater volumes of surface runoff.	Reduction in flooding over existing areas could reduce sediment transfer to the floodplain and reduce habitat quality of existing floodplain areas	Potential to increase public awareness of the importance of working with natural processes (as stated in PPS25)	Decreased flooding may have a beneficial impact on local communities, agricultural production and infrastructure
	Widening of existing rhynes and increased channel capacity	Opportunities for targeted habitat creation (UKBAP habitats *e.g.* grazing marsh).	Existing public access to be maintained. Visual amenity may be improved through planting and landscaping.	Minimal disruption to existing agricultural land use (grazing). Cost of construction is economically viable
	Disruption during construction of new structures	Temporary impact on noise, traffic and air quality levels, water quality, flora and fauna.	Temporary impact on recreation and negative impact on traditional landscape character.	

Appendix F

Options cost details

Option 10 - On-line Storage and Opening Airfield Culvert (no land costs)

includes NSC and other land area
Approx. area = 240,000 m2 (derived from volume and est. depth of 1.0m)
Approx. Volume = 480,000 m3 (lake depth to be approx 2m in order to maintain a body of water)
Airfield culvert opening works assumed to be 1,000m long

Description	Unit	Quantity	Rate £	Amount £
Scheme Costs Year 1				
GENERAL				
Design costs (outline and detailed design)	Sum			£100,000
Client costs (NSC and EA)	Sum			£40,000
Site supervision	Sum			£60,000
Site Investigation	Sum			£20,000
Site Set Up and prelims	Sum			£80,000
Service Diversions	Sum			£30,000
Open Airfield culvert (leave channel in-situ and excavate to one side)				
purchase land (29m x 1000m = 29,000m2)	ha	2.9		£0
Inlet works	sum			£20,000
Excavate low flow and compound channel (27m2/m)	m^3	27000	3.24	£87,480
Outlet works	sum			£15,000
Channel Straightening at Caravan Park (300m)				
Construct new main channel (12m2 x 300m)	m^3	3600	6.48	£23,328
Hutton & Locking Rhyne widening (460m)				
Inlet works at tilting weir	sum			£40,000
widen channel (assume 50% of new channel) [(6.7m2 X 460m)/2]	m^3	1541	6.48	£9,986
Wetland Area (540m)				
Widen and deepen small existing channel (6.7m2 x 540m)	m^3	3618	6.48	£23,445
Moor Lane Culvert				
Provision of new pre-cast culvert and headwalls, incl surfacing)	Sum			£60,000
On-line Storage Area (240,000m3)				
Land required for creation of storage lake (some already owned by NSC)	ha	24		£0
land compensation - derived from volume to be disposed of	ha	103.6		£0
Excavate topsoil (storage area) (n.e. 250mm) 240,000m2 x 250mm	m^3	60000	1.63	£97,800
Excavate topsoil (disposal area) and store onsite for re-use (n.e. 250mm) - 103.6ha x 0.25m = 259000m^3	m^3	259000	1.63	£839,160
Excavation to form flood storage (less than 2m depth) - less 10% to be used for landscaping (excl. topsoil)	m^3	372000	3.24	£1,205,280
Transport and place excavated material (incl. topsoil from lake area) on adjacent land at depth of 500mm, including trimming. Bulk factor of 1.2 - 432,000 x 1.2 = 518,400m^3	m^3	518400	2.80	£1,451,520
Provisional sum for landscaping works (assumed to be 10% of excavated material - 42,000m^3), paths, signage etc....	Sum			£100,000
Replace and trim topsoil (disposal area only) - 103.6ha	m^3	259000	2.13	£551,670
Outlet Channel back to Cross Rhyne				
Widen and deepen small existing channel (10.0m2 x 170m)	m^3	1700	6.48	£11,016
Outlet Structure to Cross Rhyne				
small outlet structure to control flows	Sum			£20,000
			Grand Total	**£4,885,684**
			Including 60% Optimism Bias	**£7,817,095**
Annual Maintenance				
Flood wall inspection and maintenance	Sum			£1,500
Control Structure Operation and Maintenance	Sum			£2,000
			Total	**£3,500**
Control Structure Replacement (Costs in years 24,49,74 and 99)				
Replacement of mechanical and electrical equipment	Sum			£50,000
Civil/Structural Repairs	Sum			£20,000
			Total	**£70,000**

Notes

1. Rate increased to allow for more precise working for channel creation (doubled excavation rate) — 6.48
2. Cost of airfield culvert opening does not include for access crossings
3. Disposal of excavated material is major cost item. If disposed to licensed site cost could be over £9m for that alone. Best option would be to investigate opportunity of letting 3rd party remove material offsite. Local developments may provide good opportunity to do this.
4. Excludes land purchase and compensation costs

Option 10 - On-line Storage and Opening Airfield Culvert (with land costs)

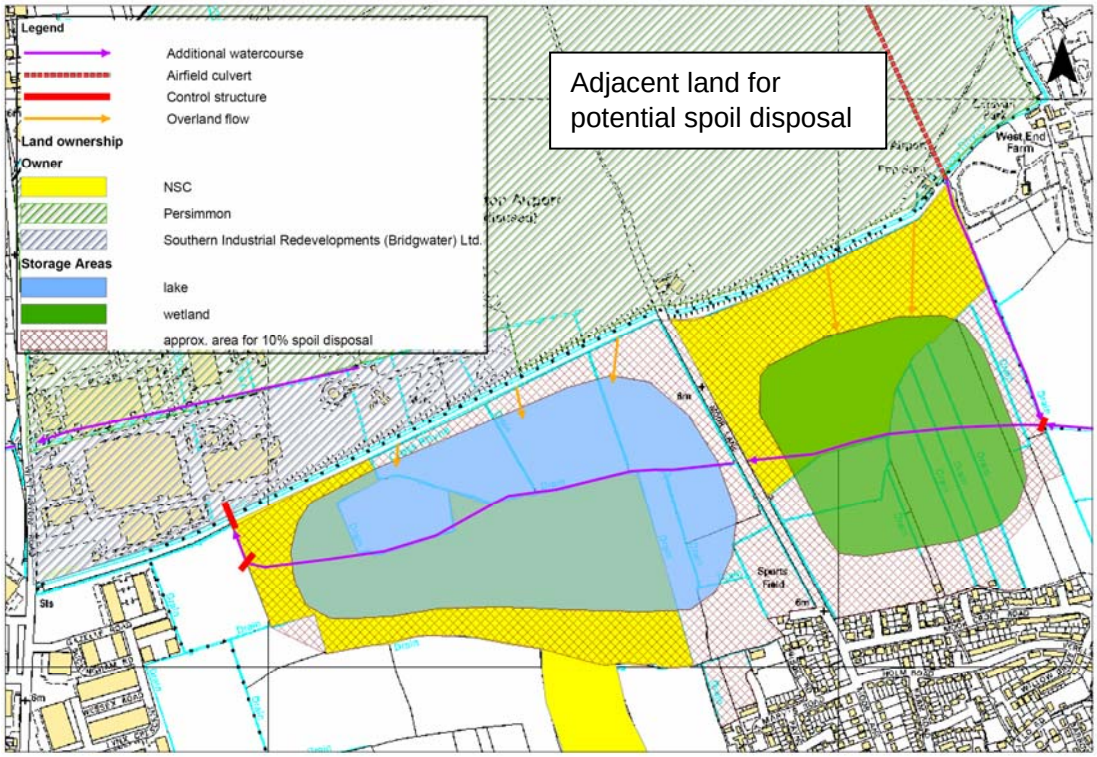
includes NSC and other land area
Approx. area = 240,000 m2 (derived from volume and est. depth of 1.0m)
Approx. Volume = 480,000 m3 (lake depth to be approx 2m in order to maintain a body of water)
Airfield culvert opening works assumed to be 1,000m long

Description	Unit	Quantity	Rate £	Amount £
Scheme Costs Year 1				
GENERAL				
Design costs (outline and detailed design)	Sum			£100,000
Client costs (NSC and EA)	Sum			£40,000
Site supervision	Sum			£60,000
Site Investigation	Sum			£20,000
Site Set Up and prelims	Sum			£80,000
Service Diversions	Sum			£30,000
Open Airfield culvert (leave channel in-situ and excavate to one side)				
purchase land (29m x 1000m = 29,000m2)	ha	2.9	3,000.00	£8,700
Inlet works	sum			£20,000
Excavate low flow and compound channel (27m2/m)	m^3	27000	3.24	£87,480
Outlet works	sum			£15,000
Channel Straightening at Caravan Park (300m)				
Construct new main channel (12m2 x 300m)	m^3	3600	6.48	£23,328
Hutton & Locking Rhyne widening (460m)				
Inlet works at tilting weir	sum			£40,000
widen channel (assume 50% of new channel) [(6.7m2 X 460m)/2]	m^3	1541	6.48	£9,986
Wetland Area (540m)				
Widen and deepen small existing channel (6.7m2 x 540m)	m^3	3618	6.48	£23,445
Moor Lane Culvert				
Provision of new pre-cast culvert and headwalls, incl surfacing)	Sum			£60,000
On-line Storage Area (240,000m3)				
Land required for creation of storage lake (some already owned by NSC)	ha	24	3,000.00	£72,000
land compensation - derived from volume to be disposed of	ha	103.6	3,000.00	£310,800
Excavate topsoil (storage area) (n.e. 250mm) 240,000m2 x 250mm	m^3	60000	1.63	£97,800
Excavate topsoil (disposal area) and store onsite for re-use (n.e. 250mm) - 103.6ha x 0.25m = 259000m^3	m^3	259000	1.63	£839,160
Excavation to form flood storage (less than 2m depth) - less 10% to be used for landscaping (excl. topsoil)	m^3	372000	3.24	£1,205,280
Transport and place excavated material (incl. topsoil from lake area) on adjacent land at depth of 500mm, including trimming. Bulk factor of 1.2 - 432,000 x 1.2 = 518,400m^3	m^3	518400	2.80	£1,451,520
Provisional sum for landscaping works (assumed to be 10% of excavated material - 42,000m^3), paths, signage etc....	Sum			£100,000
Replace and trim topsoil (disposal area only) - 103.6ha	m^3	259000	2.13	£551,670
Outlet Channel back to Cross Rhyne				
Widen and deepen small existing channel (10.0m2 x 170m)	m^3	1700	6.48	£11,016
Outlet Structure to Cross Rhyne				
small outlet structure to control flows	Sum			£20,000
			Grand Total	**£5,277,184**
			Including 60% Optimism Bias	**£8,443,495**
Annual Maintenance				
Flood wall inspection and maintenance	Sum			£1,500
Control Structure Operation and Maintenance	Sum			£2,000
			Total	**£3,500**
Control Structure Replacement (Costs in years 24,49,74 and 99)				
Replacement of mechanical and electrical equipment	Sum			£50,000
Civil/Structural Repairs	Sum			£20,000
			Total	**£70,000**

Notes

1. Rate increased to allow for more precise working for channel creation (doubled excavation rate) — 6.48
2. Cost of airfield culvert opening does not include for access crossings
3. Disposal of excavated material is major cost item. If disposed to licensed site cost could be over £9m for that alone. Best option would be to investigate opportunity of letting 3rd party remove material offsite. Local developments may provide good opportunity to do this.
4. Excludes land purchase and compensation costs

Potential land area required for Uphill Great Rhyne catchment



Compound Channel - St. George's (no land costs)

Create compound channel to locally lower levels - lower right hand bank by approx 1m for 50m width
- assumed that material to be spread at 0.5m depth over adjacent land (100% land value compensation to be paid)
Compound channel area = 1920m x 50m = 96,000m^2
Compound channel volume = 96,000m^2 x 1m = 96,000m^3
Between Chainage 1865m and 3785m (1920m length)
Raise local low spots in left bank (approx 100m length) -To retain 300mm freeboard (current river geometry), left bank to be raised over 100m length by av. 140mm

Description	Unit	Quantity	Rate £	Amount £	
Scheme Costs Year 1					
General					
Design costs (outline and detailed design)	Sum			£35,000	
Client costs (NSC and EA)	Sum			£15,000	
Site supervision	Sum			£20,000	
Site Investigation and testing	Sum			£25,000	
Site Set Up and prelims (15% of works)	Sum			£40,000	
Service Diversions	Sum			£10,000	
land purchase (9.6ha)	ha	9.6		£0	
land compensation (17.3ha) - derived from volume to be disposed of	ha	17.3		£0	
Compound Channel					
Site clearance	sum			£20,000	
Excavate topsoil and store onsite for re-use (n.e. 250mm)	m^3	24000	1.63	£39,120	
Excavation to form compound channel (excl. topsoil)	m^3	72000	2.15	£154,800	
Excavate topsoil (disposal area) and store onsite for re-use (n.e. 250mm)	m^3	48000	1.63	£78,240	
Transport and place excavated material on adjacent land (up to 200m) at depth of 500mm, including trimming. Bulk factor of 1.2 - 72,000 x 1.2 = 86,400m^3	m^3	86400	2.80	£241,920	
Replace and trim topsoil	m^3	72000	2.13	£153,360	
Form batter (1:2) and trim (2.24m x 1920m)	m^3	4300	1.13	£4,859	
Fencing (post and wire)	m	2020	7.77	£15,695	
Sub-total				**£852,994**	1364791.04
Raise Left bank low spots					
Construct 300mm high earth bank on left bank at three locations. Total length = 190m 1m width 1:2 side slopes	m	190	250.00	£47,500	
Sub-total				**£47,500**	76000
			Grand Total	**£900,494**	
			Incl 60% Optimism bias =	**£1,440,791**	1440791.04
Annual Maintenance					
Weed clearance	sum			£4,000	
			Total	**£4,000**	

Notes

1. * Approx rate from Dave Crowson/Barry Underwood
2. ** Approx rates from local contractor
3. Rates are taken from 'Spon Estimating' 2006
4. Excludes land purchase and compensation costs

Compound Channel - St. George's (with land costs)

Create compound channel to locally lower levels - lower right hand bank by approx 1m for 50m width
- assumed that material to be spread at 0.5m depth over adjacent land (100% land value compensation to be paid)
Compound channel area = 1920m x 50m = 96,000m^2
Compound channel volume = 96,000m^2 x 1m = 96,000m^3
Between Chainage 1865m and 3785m (1920m length)
Raise local low spots in left bank (approx 100m length) -To retain 300mm freeboard (current river geometry), left bank to be raised over 100m length by av. 140mm

Description	Unit	Quantity	Rate £	Amount £	
Scheme Costs Year 1					
General					
Design costs (outline and detailed design)	Sum			£35,000	
Client costs (NSC and EA)	Sum			£15,000	
Site supervision	Sum			£20,000	
Site Investigation and testing	Sum			£25,000	
Site Set Up and prelims (15% of works)	Sum			£40,000	
Service Diversions	Sum			£10,000	
land purchase (9.6ha)	ha	9.6	3,000	£28,800	
land compensation (17.3ha) - derived from volume to be disposed of	ha	17.3	3,000	£51,900	
Compound Channel					
Site clearance	sum			£20,000	
Excavate topsoil and store onsite for re-use (n.e. 250mm)	m^3	24000	1.63	£39,120	
Excavation to form compound channel (excl. topsoil)	m^3	72000	2.15	£154,800	
Excavate topsoil (disposal area) and store onsite for re-use (n.e. 250mm)	m^3	48000	1.63	£78,240	
Transport and place excavated material on adjacent land (up to 200m) at depth of 500mm, including trimming. Bulk factor of 1.2 - 72,000 x 1.2 = 86,400m^3	m^3	86400	2.80	£241,920	
Replace and trim topsoil	m^3	72000	2.13	£153,360	
Form batter (1:2) and trim (2.24m x 1920m)	m^3	4300	1.13	£4,859	
Fencing (post and wire)	m	2020	7.77	£15,695	
Sub-total				**£933,694**	1493911.04
Raise Left bank low spots					
Construct 300mm high earth bank on left bank at three locations. Total length = 190m 1m width 1:2 side slopes	m	190	250.00	£47,500	
Sub-total				**£47,500**	76000
			Grand Total	**£981,194**	
			Incl 60% Optimism bias =	**£1,569,911**	1569911.04
Annual Maintenance					
Weed clearance	sum			£4,000	
			Total	**£4,000**	

Notes

1. * Approx rate from Dave Crowson/Barry Underwood
2. ** Approx rates from local contractor
3. Rates are taken from 'Spon Estimating' 2006
4. Excludes land purchase and compensation costs

Appendix G

Additional Planning Guidance

GENERAL GUIDANCE

This report is a high level flood risk assessment of the Weston-super-Mare area. In accordance with Government planning policy flood risk within the area can be categorised into three flood risk zones – Zone 1 (Little or no risk), Zone 2 (Low to medium risk) and Zone 3 (Medium to high risk). This categorisation into zones is intended to give an indication only of flood risk at any particular location within the area and is not intended to represent a detailed assessment of the flood risk appertaining to any particular building or piece of land within the study area

The Government aims to reduce the risk from flooding to people and the developed and natural environment by discouraging development within areas at medium to high risk of flooding. Government guidance has been produced for local planning authorities to help them when allocating land for development in order to meet this aim.

The current guidance is contained in Planning Policy Statement 25: Development and Flood Risk (PPS25). The key planning objectives and decision making principles remain essentially unchanged in these two documents, however the risk based sequential test has altered.

Therefore, this additional planning guidance is intended to be used by planners and developers alike to assess the suitability of any particular site to support or not a particular type of development and is the guidance that would also be available as part of a SFRA for North Somerset District Council. This is subject to the level of flood risk, the vulnerability of the proposed usage and the extent to which the combination of other factors and mitigation might exempt the development from the application of this guidance (i.e. flood risk would not be a reason for refusal at planning).

The assessment, whether for the purpose of producing a Local Development Plan, assessing the flood risk of an existing property or parcel of land comprises of 3 stages:

Flood Risk Vulnerability Classification (Table D2 PPS25)
Sequential Test through the use of PPS25 Decision Flow Charts
Exception Test (where needed)

Flood Risk Vulnerability Classification

Prior to the Sequential Test a flood risk classification which groups land uses, infrastructure and buildings into five categories of vulnerability needs to be carried out to assign one of five vulnerability criteria to the proposed development site(s). A summary of these classifications, with examples of the elements which lie within them, are outlined in table G.1.

Table G.1
PPS 25: Flood Risk Vulnerability Classification

Flood Risk Vulnerability Classification	
1.Essential Infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Strategic utility infrastructure, including electricity generating power stations and grid and primary substations.
2. Highly Vulnerable	• Police stations, Ambulance stations, Fire stations, Command Centres and telecommunications installations required to be operational during flooding. • Emergency dispersal points. • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent

	residential use. • Installations requiring hazardous substances consent.
3. More Vulnerable	• Hospitals • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for: dwellings houses; student halls of residence; drinking establishments; nightclubs; and hotels. • Non-residential uses for health services, nurseries and educational establishments. • Landfill and sites used for waste management facilities for hazardous waste. • Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.
4. Less Vulnerable	• Buildings used for: shops; financial; professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non-residential institutions not included in 'more vulnerable'; and assembly and leisure. • Land and building used for agriculture and forestry. • Waste treatment (except landfill and hazardous waste facilities). • Minerals working and processing (except for sand and gravel working). • Water treatment plants. • Sewage treatment plants (if adequate pollution control measures are in place).
5. Water-compatible Development	• Flood control infrastructure. • Water transmission infrastructure and pumping stations. • Sewage transmission infrastructure and pumping stations. • Sand and gravel workings. • Docks, marinas and wharves. • Navigation facilities. • MOD defence installations. • Shop building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. • Water-based recreation (excluding sleeping accommodation). • Lifeguard and coastguard stations. • Amenity open space, nature conservation and biodiversity, outdoor sports, recreation and essential facilities e.g. changing rooms. • Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

Notes

- *This classification is based on partly on Defra/Environment Agency research on flood risks to people and also the need of some uses to keep functioning during flooding.*
- *Buildings with combined activities should be placed in the higher of the relevant classes of flood risk sensitivity. Developments that allow uses to be distributed over the site may fall within several classes of flood risk sensitivity.*
- *The impact of a flood on the particular uses identified within this flood risk vulnerability classification will vary within each vulnerability class. Therefore, the flood risk management infrastructure and other risk mitigation measures needed to ensure the development is safe may differ between uses within a particular vulnerability classification.*
- *Some elements of classifications are subject to a specific warning and evacuation plan.*

The Sequential Test

The Government expects local planning authorities to apply a risk based approach to the preparation of development plans and their decisions on development control through the revised sequential test. Developers should also look for guidance from this test and bear it in mind when considering developments. When creating or revising

policies in development plans and in considering applications for development, local planning authorities should give priority in allocating or permitting sites for development, starting from lowest flood risk. Attention should also be paid to the sub-divisions, a and b, in Zone 3. The assessment of developments within high risk areas are no longer assessed under PPS25, in terms of developed areas (PPG25 3a) or undeveloped and sparsely populated areas (PPG25 3b) as this sub division of categories has been removed. Functional floodplain remains as a category in its own right.

The Sequential Test is central in determining the suitability of land for development in flood risk areas and should be applied at all levels of the planning process. It aims to guide decision-makers to allocating new developments to areas with the lowest probability of flooding (Zone 1) and to account for vulnerability where sites have to be placed in higher risk areas. The Sequential Test should be applied by local authorities in land allocation for spatial plans and by developers wishing to develop sites which are at risk from fluvial or tidal flooding. Additionally this type of approach should be used in areas at risk from other forms of flooding. Table G.2 below details the type of development permitted in each flood zone, along with any FRA or developer requirements. Table G.3 summarises the relationship between the different Flood Zones and the Flood Risk Vulnerability classifications.

Table G.2
PPS25: Planning response to sequential characterisation of flood risk

Zone 1 Low Probability

Definition
This zone comprises land assessed as having a less than 1 in 1000 annual probability of fluvial or tidal flooding in any year (<0.1%).

Appropriate uses
All uses of land are appropriate in this zone.

FRA requirements
An FRA is required for development proposals on sites comprising one hectare or above. The FRA should include information regarding:

- the vulnerability to flooding from other sources as well as fluvial and tidal flooding;
- the potential to increase flood risk elsewhere through the addition of hard surfaces; and
- the effect of the new development on surface water run-off.

This need only be brief unless the factors above or other local considerations require particular attention. See PPS25 Annex E for minimum requirements.

Policy aims
In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area and beyond through the layout and form of the development, and the appropriate application of sustainable drainage techniques.

Zone 2 Medium Probability

Definition
This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of fluvial flooding (1% – 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of tidal flooding (0.5% – 0.1%) in any year.

Appropriate uses
The water-compatible, less vulnerable and more vulnerable uses of land and essential infrastructure are appropriate in this zone. Subject to the Sequential Test being applied, the highly vulnerable uses are only appropriate in this zone if the Exception Test is passed.

FRA requirements
All development proposals in this zone should be accompanied by a FRA. See PPS25 Annex E for minimum requirements.

Policy aims
In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout and form of the development, and the appropriate application of sustainable drainage techniques.

Zone 3a High Probability

Definition
This zone comprises land assessed as having a 1 in 100 or greater annual probability of fluvial flooding (>1%) or a 1 in 200 or greater annual probability of tidal flooding (>0.5%) in any year.

Appropriate uses
The water-compatible and less vulnerable uses of land are appropriate in this zone. The highly vulnerable uses should not be permitted in this zone. The more vulnerable and essential infrastructure uses should only be permitted in this zone if the Exception Test is passed. Essential infrastructure permitted in this zone should be designed and constructed to remain operational and safe for users in times of flood.

FRA requirements
All development proposals in this zone should be accompanied by a FRA. See PPS25 Annex E for minimum requirements.

Policy aims
In this zone, developers and local authorities should seek opportunities to:
- reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques;
- relocate existing development to land in zones with a lower probability of flooding; and
- create space for flooding to occur by restoring functional floodplain and flood flow pathways and by identifying, allocating and safeguarding open space for flood storage.

Zone 3b The Functional Floodplain

Definition
This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).

Appropriate uses
Only the water-compatible uses and the essential infrastructure that has to be there should be permitted in this zone. It should be designed and constructed to:
- remain operational and safe for users in times of flood;
- result in no net loss of floodplain storage;
- not impede water flows; and
- not increase flood risk elsewhere.

Essential infrastructure in this zone should pass the Exception Test.

FRA requirements
All development proposals in this zone should be accompanied by a FRA. See PPS25 Annex E for minimum requirements.

Policy aims
In this zone, developers and local authorities should seek opportunities to:

- reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques; and
- relocate existing development to land with a lower probability of flooding.

Table G.3
Flood Risk Vulnerability and Flood Zone 'Compatibility'

Flood Zone	Flood Risk Vulnerability Classification				
	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	✓	ET	✓	✓
Zone 3a	ET	✓	×	ET	✓
Zone 3b	ET	✓	×	×	×

Key:
✓ = Development is appropriate
× = Development should not be permitted
ET = Exception test must be passed for the development to be permitted.

In applying the sequential test, local planning authorities should consult and take the advice of the Environment Agency on the distribution of flood risk and the availability of flood defences in their areas. Flood defences for most new housing developments should be designed and constructed to protect against a flood with an annual probability of 1% for fluvial flooding and 0.5% for coastal flooding (for a period of 50 years). Commercial and industrial development should aim to achieve the same minimum standard of defence.

As part of this guidance, PPS25 Decision Flow Charts have been produced using the information given in the sequential test (table G.2). The flow charts can be followed by planning officers, potential developers and members of the public to assess at a strategic level the flood risk to a piece of land. They clearly indicate whether a piece of land would require a specific and detailed Flood Risk Assessment to be provided with a planning application and are designed to provide a robust and consistent system for assessing flood risk anywhere within Weston-super-Mare. The PPS25 Decision Flow Charts are in Appendix G and follow there is a flow chart for each of the Vulnerability Classifications given in table G.1.

The Exception Test

In circumstances where the Sequential Test has been applied, and possible development locations cannot be found in zones of lower probability of risk, then the Exception Test can be applied as indicated on the PPS25 Decision Flow Charts. The Exception Test should only be used where there are large areas within Environment Agency Flood Zones 2 or 3 where the wider aims of sustainable development need to be addressed. When required the decision-makers should apply the Exception Test at the earliest possible stage of the planning process. It should be applied to all Local Development Documents (LLD) as well as all planning applications with the exceptions of domestic extensions and householder developments.

For the Exception Test to be passed:

- It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh the flood risk.

- The development must be on developable brownfield land, unless no reasonable alternative options exist.
- Have a flood risk assessment to accompany the application. The FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and where possible will reduce the overall flood risk.

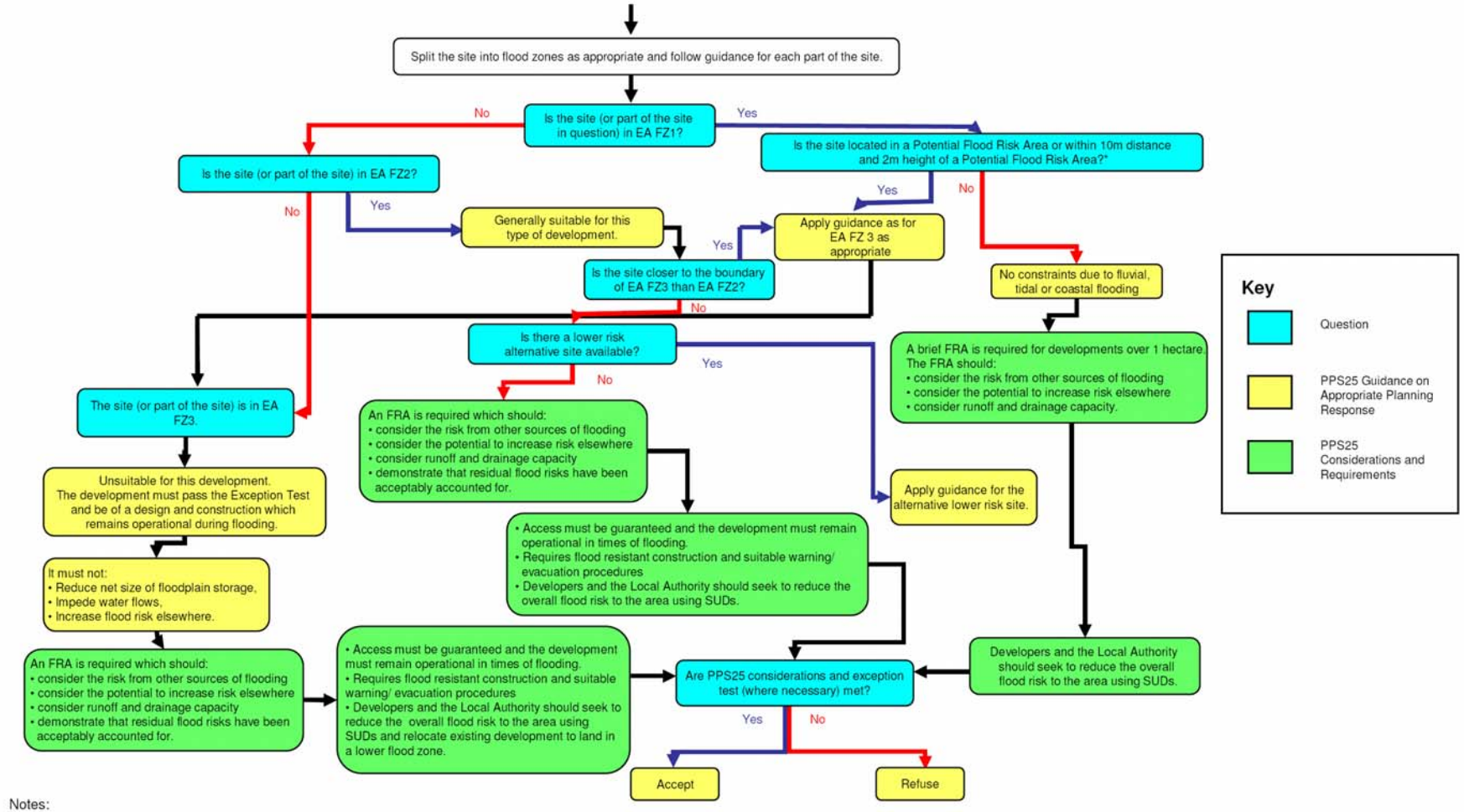
The Exception Test should be used in locations with extensive areas liable to flooding or areas where restrictive designations such as landscape and nature conservation designations, e.g. Areas of Outstanding Natural Beauty (AONB) and Sites of Special Scientific Interest (SSSIs) reduce the amount of available land for the sustainable development required. In addition, the compliance with each part of the Exception Test must be demonstrated in an open and transparent way.

The Exception Test should not be used to justify 'highly vulnerable' development in Flood Zone 3a or 'less vulnerable'; 'more vulnerable'; or 'highly vulnerable' development in Flood Zone 3b.

Additional guidance

Certain properties will fall within a Flood Zone or Potential Flood Risk Area. This information is not meant to alarm residents of Weston-super-Mare, but provides a warning to prepare for potential flooding should it happen. Flooding could happen at almost any time, but in any individual year the risk of a flood may be low. The Environment Agency publishes advice on dealing with flood risk and installing preventative measures. The advice can be obtained by contacting Floodline on 0845 988 1188 or through the Environment Agency website at www.environment-agency.gov.uk. Individuals and developers should also consider their responsibilities for what to do to reduce the flood risk to themselves and others, their property and the people who use it. Guidance is provided for the review of Flood Risk Assessments and the benefits, implementation and value SUDs.

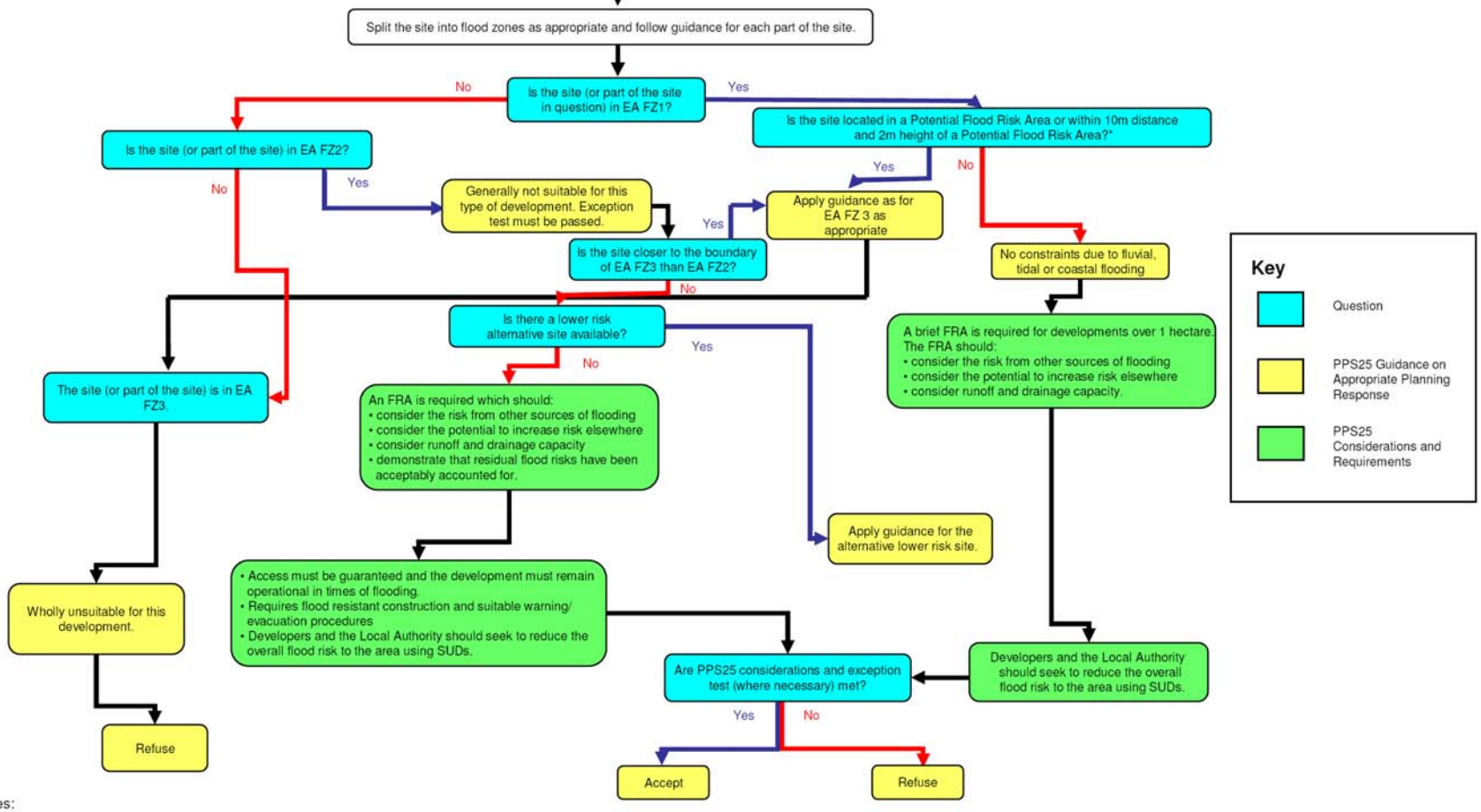
PPS25 Flow Chart 1 – Essential Infrastructure



Notes:

1. All risks relate to the time at which a land allocation decision is made or an application submitted
2. Development should not be permitted where existing sea or river defences, properly maintained, would not provide an acceptable standard of safety over the lifetime of the development, as such land would be extremely vulnerable should a flood defence embankment or sea wall be breached, in particular because of the speed of flooding in such circumstances.
3. Minimum standard of defence for fluvial risk areas is 1:100 + climate change, and for tidal risk areas is 1:200 + climate change.
4. Information above based on Table 6.2 in the SFRA (Planning response to sequential characterisation of flood risk). Refer to PPS25 for more detailed guidance.
5. *This width and height allowance of 10m and 2m is to take into account the potential increase in the extent of the Potential Flood Risk Area due to climate change and the large uncertainty in the extents of the Potential Flood Risk Areas.

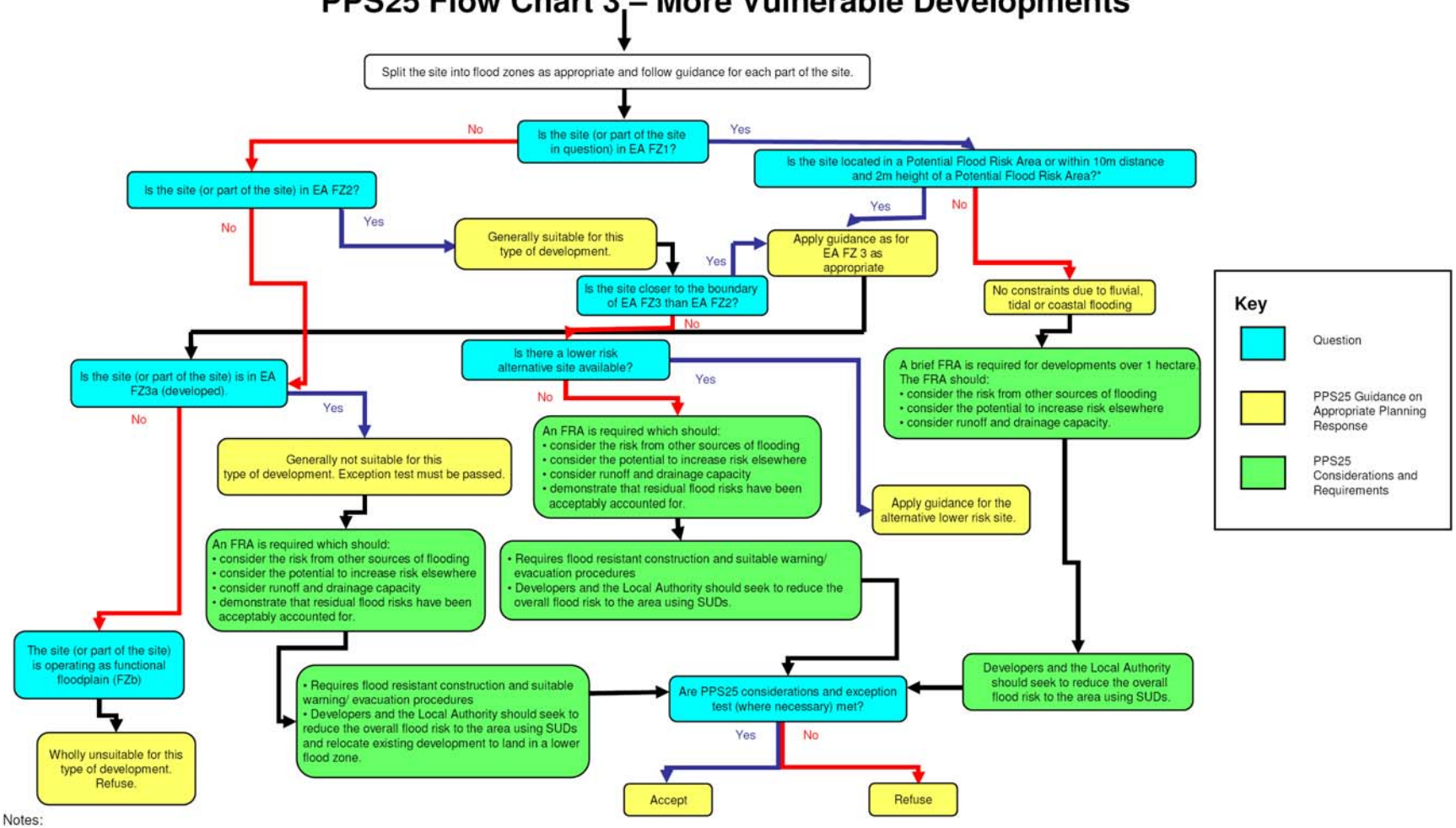
PPS25 Flow Chart 2 – Highly Vulnerable Developments



Notes:

1. All risks relate to the time at which a land allocation decision is made or an application submitted
2. Development should not be permitted where existing sea or river defences, properly maintained, would not provide an acceptable standard of safety over the lifetime of the development, as such land would be extremely vulnerable should a flood defence embankment or sea wall be breached, in particular because of the speed of flooding in such circumstances.
3. Minimum standard of defence for fluvial risk areas is 1:100 + climate change, and for tidal risk areas is 1:200 + climate change.
4. Information above based on Table 6.2 in the SFRA (Planning response to sequential characterisation of flood risk). Refer to PPS25 for more detailed guidance.
5. *This width and height allowance of 10m and 2m is to take into account the potential increase in the extent of the Potential Flood Risk Area due to climate change and the large uncertainty in the extents of the Potential Flood Risk Areas.

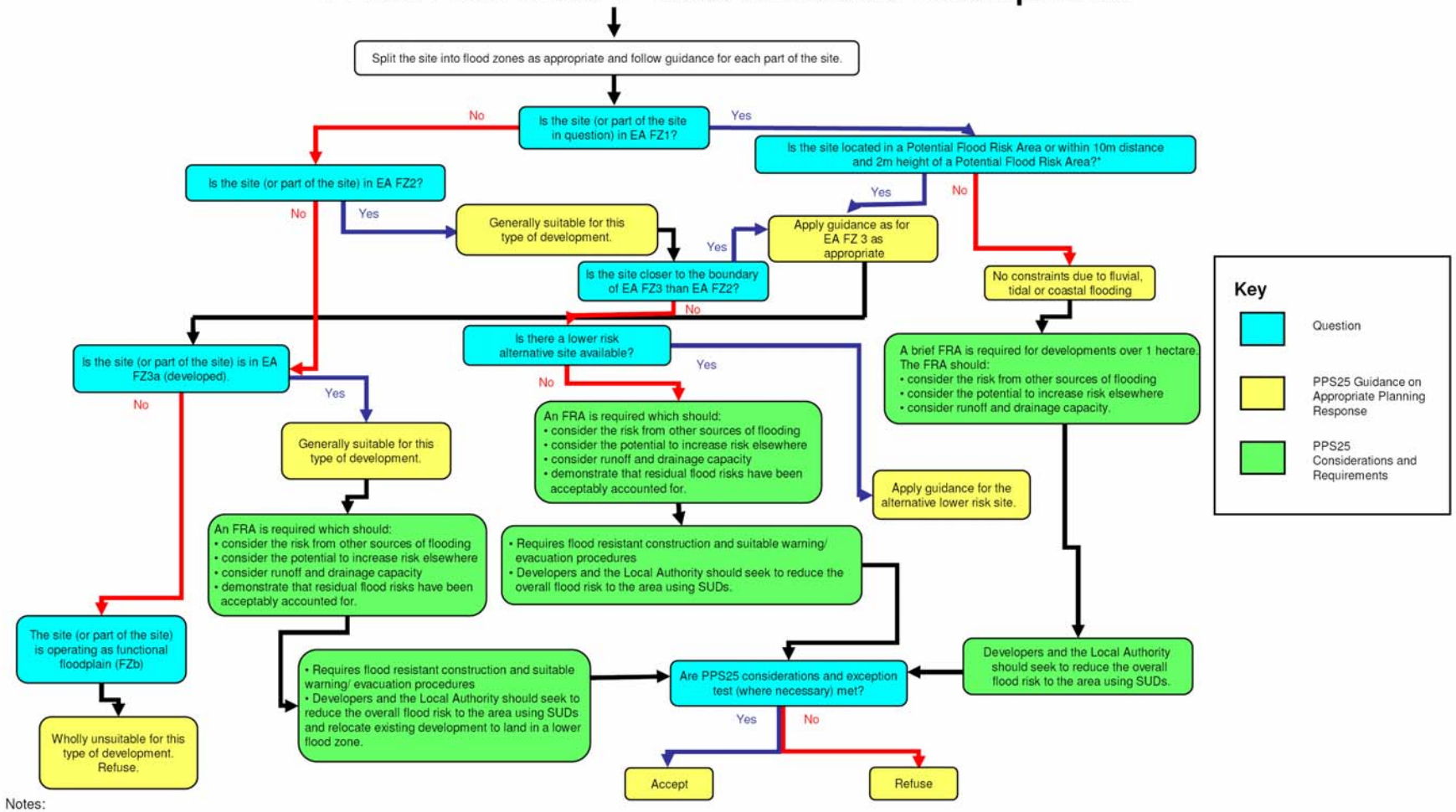
PPS25 Flow Chart 3 – More Vulnerable Developments



Notes:

1. All risks relate to the time at which a land allocation decision is made or an application submitted
2. Development should not be permitted where existing sea or river defences, properly maintained, would not provide an acceptable standard of safety over the lifetime of the development, as such land would be extremely vulnerable should a flood defence embankment or sea wall be breached, in particular because of the speed of flooding in such circumstances.
3. Minimum standard of defence for fluvial risk areas is 1:100 + climate change, and for tidal risk areas is 1:200 + climate change.
4. Information above based on Table 6.2 in the SFRA (Planning response to sequential characterisation of flood risk). Refer to PPS25 for more detailed guidance.
5. *This width and height allowance of 10m and 2m is to take into account the potential increase in the extent of the Potential Flood Risk Area due to climate change and the large uncertainty in the extents of the Potential Flood Risk Areas.

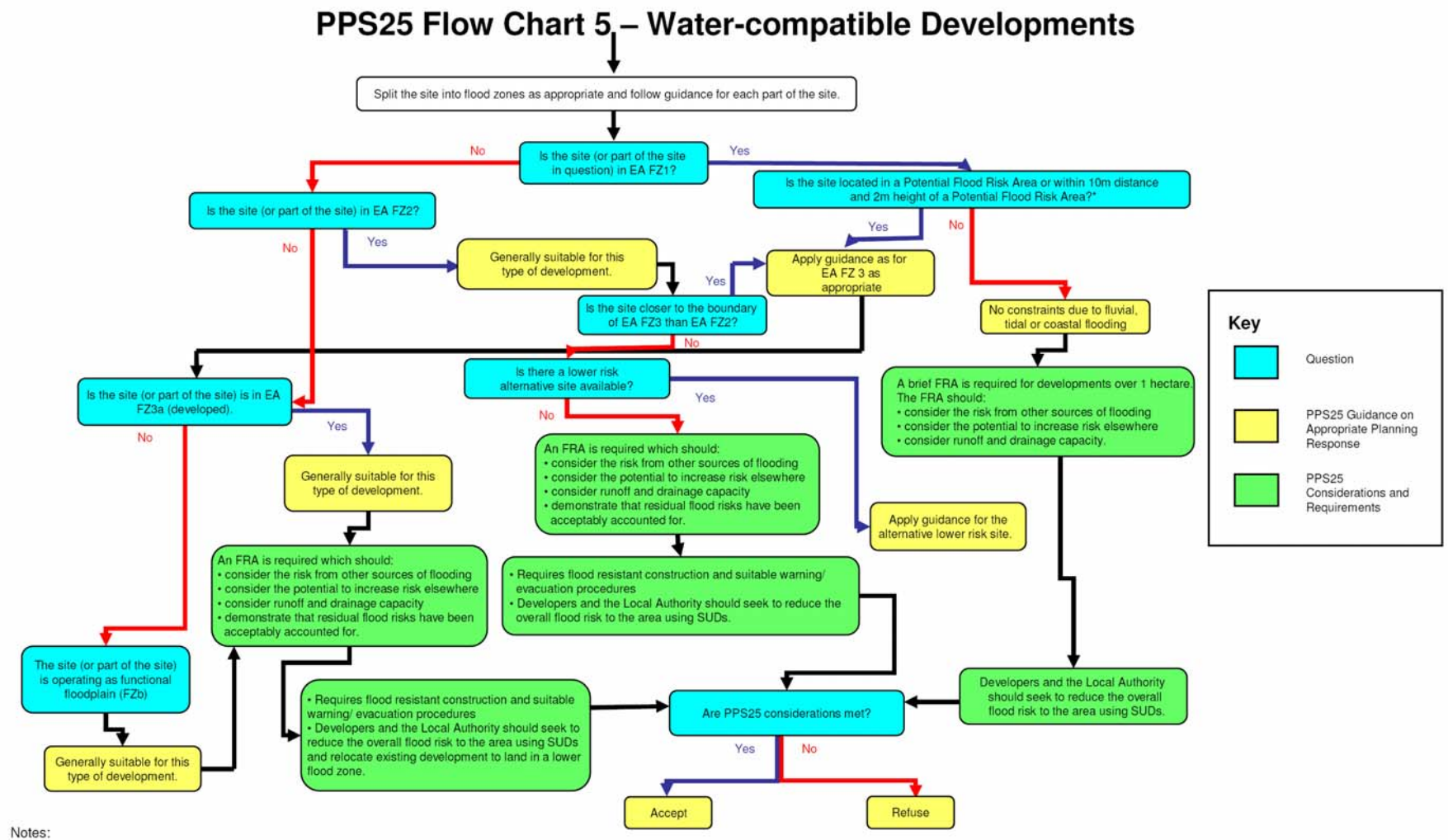
PPS25 Flow Chart 4 – Less Vulnerable Developments



Notes:

1. All risks relate to the time at which a land allocation decision is made or an application submitted
2. Development should not be permitted where existing sea or river defences, properly maintained, would not provide an acceptable standard of safety over the lifetime of the development, as such land would be extremely vulnerable should a flood defence embankment or sea wall be breached, in particular because of the speed of flooding in such circumstances.
3. Minimum standard of defence for fluvial risk areas is 1:100 + climate change, and for tidal risk areas is 1:200 + climate change.
4. Information above based on Table 6.2 in the SFRA (Planning response to sequential characterisation of flood risk). Refer to PPS25 for more detailed guidance.
5. *This width and height allowance of 10m and 2m is to take into account the potential increase in the extent of the Potential Flood Risk Area due to climate change and the large uncertainty in the extents of the Potential Flood Risk Areas.

PPS25 Flow Chart 5 – Water-compatible Developments



Notes:

1. All risks relate to the time at which a land allocation decision is made or an application submitted
2. Development should not be permitted where existing sea or river defences, properly maintained, would not provide an acceptable standard of safety over the lifetime of the development, as such land would be extremely vulnerable should a flood defence embankment or sea wall be breached, in particular because of the speed of flooding in such circumstances.
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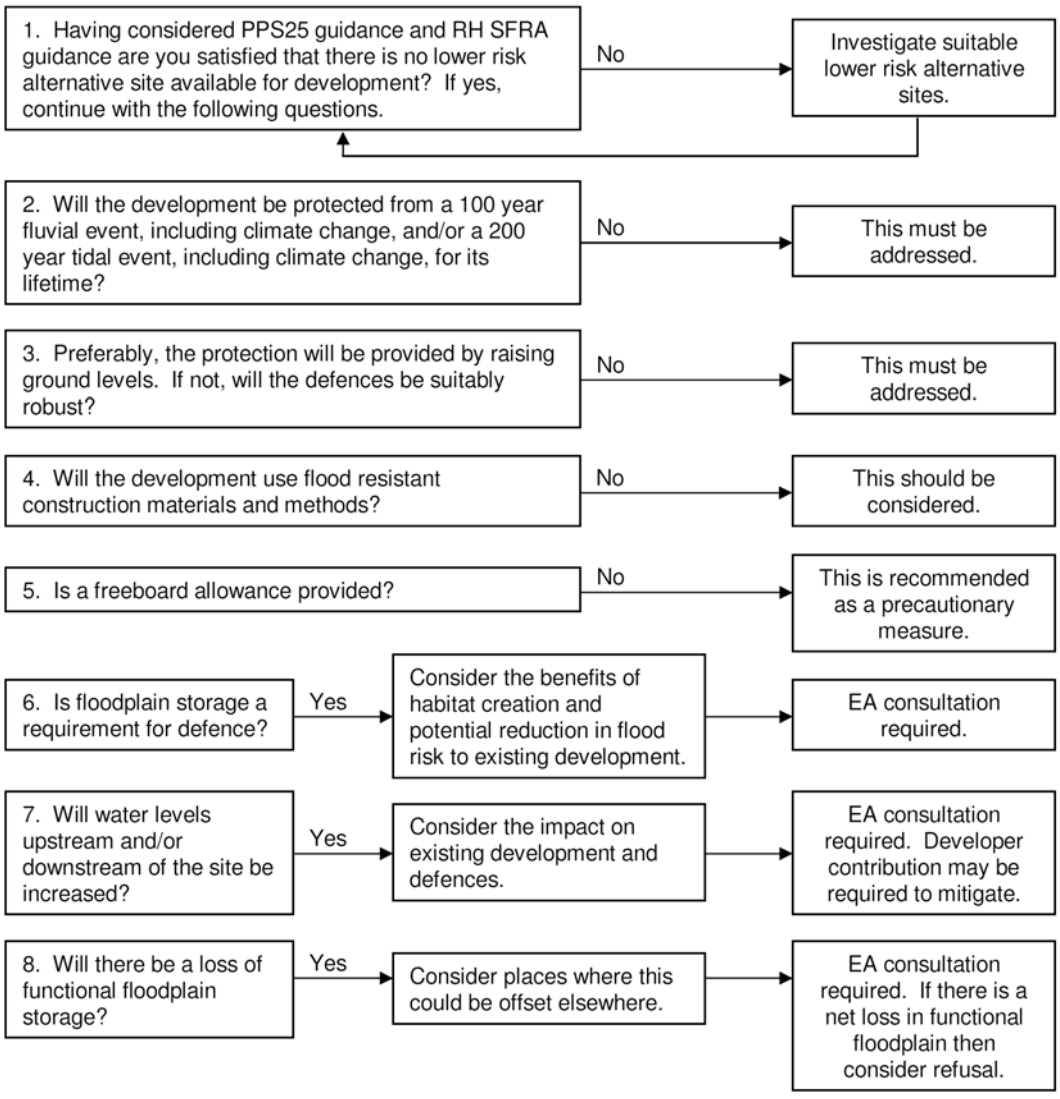
4. Information above based on Table 6.2 in the SFRA (Planning response to sequential characterisation of flood risk). Refer to PPS25 for more detailed guidance.
5. *This width and height allowance of 10m and 2m is to take into account the potential increase in the extent of the Potential Flood Risk Area due to climate change and the large uncertainty in the extents of the Potential Flood Risk Areas.

Review of Flood Risk Assessment –

Residential / Commercial / Industrial Development

Method:

Below is a checklist for Planners reviewing FRAs for residential, commercial and industrial development sites within or treated as within EA Flood Zones 2, 3a and 3b. It contains a list of questions which address areas highlighted as important in an FRA by PPS25. All questions should be answered before the final decision is made. In reviewing each question you must be satisfied that the FRA has adequately dealt with the issue. If you are not satisfied, the required action is shown. If you are satisfied then move on to the next question. Once you have reviewed all the questions, an overall decision about the suitability of the site for development can be made. Question 1 is the only question where the answer **MUST** be yes before you can proceed with the following questions.



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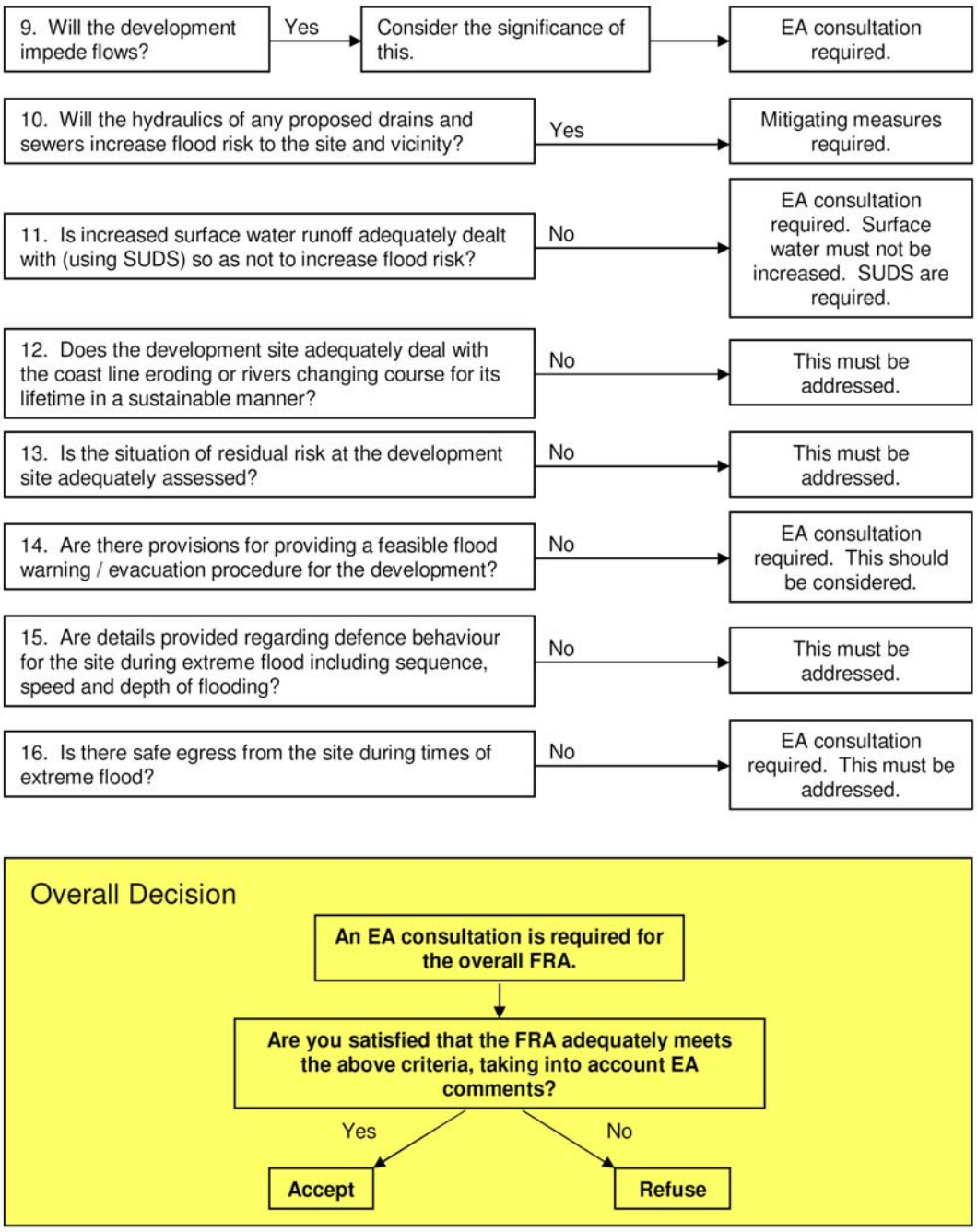


Surface water and Sustainable Drainage Systems (SUDS)

Flood risk from surface water flooding is of concern within the study area. The Environment Agency 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.

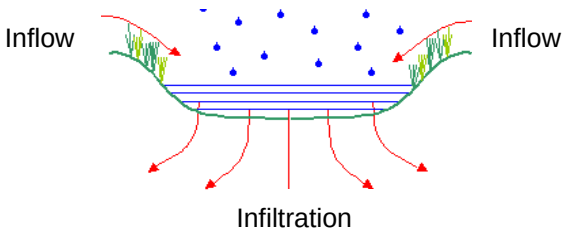
In addition, they can be used to create more imaginative and attractive developments and are designed so that less damage is done, than conventional systems, if their capacity is exceeded.

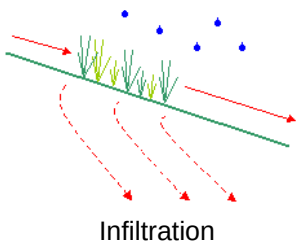
Surface water management using SUDS can be implemented at all scales and in most urban settings, ranging from hard-surfaced areas to soft landscaped features, even if there is limited space. Most techniques use infiltration but even if the area has little or no infiltration SUDS can still are used in 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 G1a) are long shallow channels whilst filter strips (figure G1b) 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.



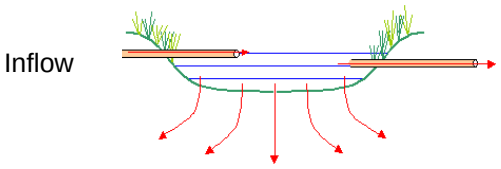


c. **Permeable surfaces and filter drains** – these are devices that have a volume of permeable material below ground to store surface water. Runoff flows to this storage area via a permeable surface.

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 G1c.

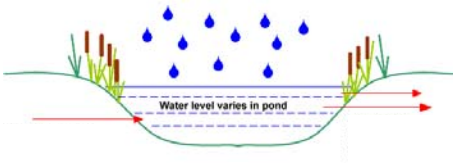
e. **Basins and ponds** – these are areas for storage of surface runoff e.g. floodplains, wetlands, and flood storage reservoirs. They can be designed to control flows by storing water then releasing it slowly once the risk of flooding has passed. See figure G1d.

Figure G1c - Cross-section through an Infiltration Basin



Infiltration

Figure G1d - Cross-section of a Pond



Water level varies in the pond

APPENDIX H

Environmental Data