ARUP

Bristol City Council

Bristol Avon Flood Strategy

Strategic Outline Case Technical Document

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Executive Summary

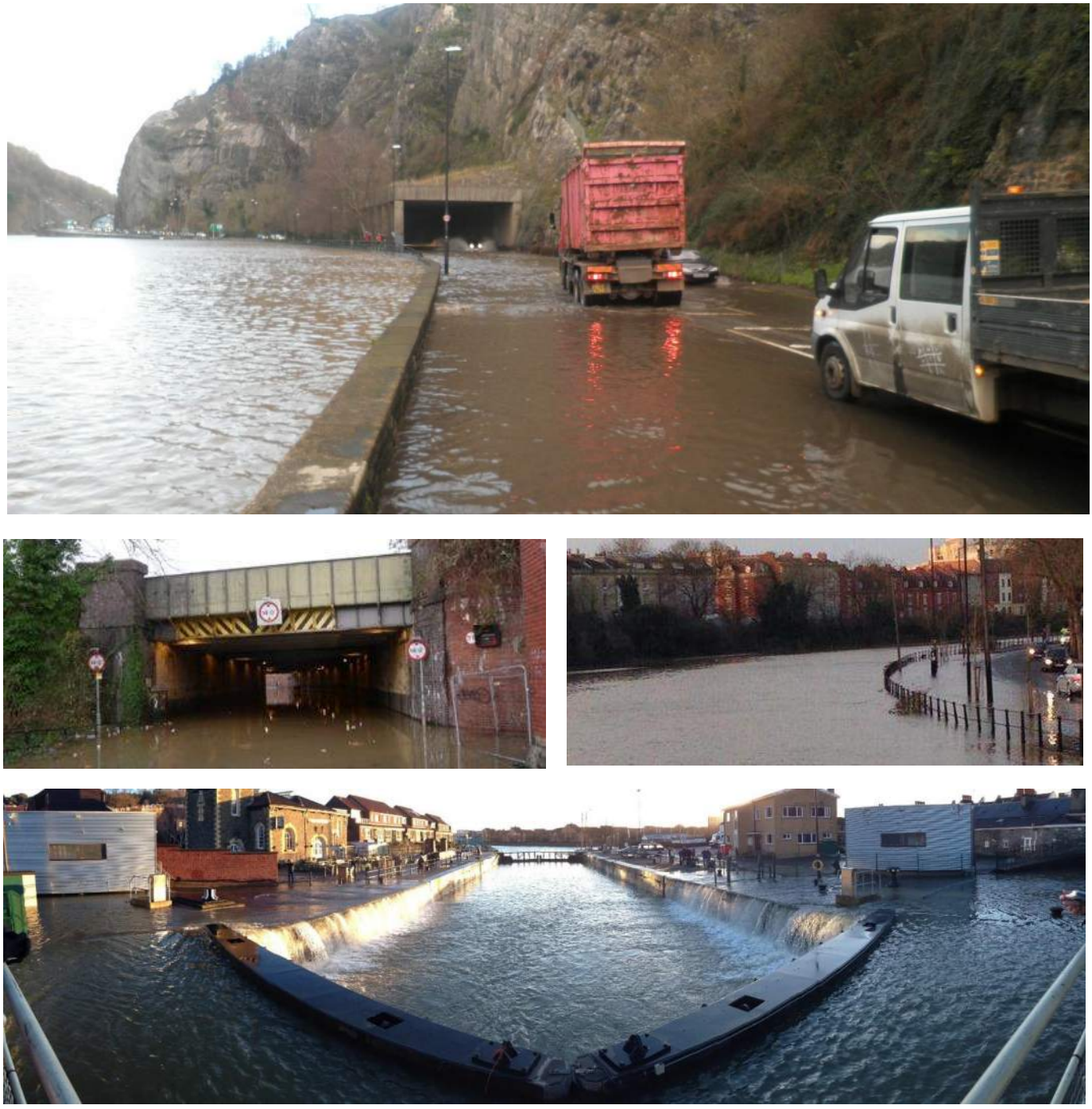

Figure 1: January 2014 tidal surge inundating the A4 Portway in the Avon Gorge (top), Cattlemarket Road (left) and Clarence Road (right), and outflanking tidal flood gates at Junction Lock into the Floating Harbour (bottom).

1 Executive Summary

Bristol and its neighbouring communities have grown and thrived on the banks of the River Avon. However, people and property face an increasing risk of flooding. Storms can increase flows coming down the river or can also force tidal water to surge up the Severn Estuary. Large parts of Bristol's centre are vulnerable to the River Avon overtopping low spots and also causing water within the harbour to flood properties. Flood risk is increasing due to climate change causing sea levels to rise and causing storms to increase in frequency and severity.

A major flood event that currently has a 0.5% (1 in 200) annual chance of occurring now, could become as frequent as once a year by the end of the century if no strategic management of the risk is implemented.

Bristol City Council (BCC) and the Environment Agency (EA) are working together to deliver a long-term plan to better protect homes, businesses and infrastructure from flooding from the River Avon. This is a unique opportunity to enhance the river for all by creating a more resilient, active and sustainable city that can meet the future needs of its residents, businesses and visitors.

This report sets out the Strategic Outline Case (SOC) to deliver a strategic flood risk management approach to the single benefit area of central Bristol (plus measures upstream and downstream to ensure no adverse impact). The SOC is in accordance with the HM Treasury Green Book and Flood and Coastal Erosion Risk Management (FCERM) Appraisal Guidance principles. The SOC covers the Bristol Avon Flood Strategy – referred to as the Strategy throughout this document.

1.1 Strategy objectives

The key investment objectives for the Strategy have been set to reflect the importance of delivering robust and sustainable flood risk management infrastructure for the strategy area, whilst acknowledging the importance of the area for employment purposes and future redevelopment opportunities. They are as follows:

- To support the safe living, working and travelling in and around central Bristol by ensuring flood threat is reduced and measures address residual risks.
- To facilitate the sustainable growth of Bristol and the West of England by supporting opportunities for employment and residential land, and infrastructure.
- To maintain natural, historic, visual and built environments within the waterfront corridor and where possible deliver enhanced recreational, heritage and wildlife spaces.
- To ensure navigation of river and marine activities continues.
- To ensure the strategy is technically feasible and deliverable.

These have been used to evaluate the flood risk management strategic approaches and to support the appraisal process. In addition, the following objectives have been developed in relation to placemaking opportunities, following the identification of a preferred way forward:

- To enhance walking and cycling links to enable greater access to opportunity work and housing.
- To bring existing communities closer together, as well as providing the opportunity to unlock new development land and attract residents, businesses and visitors.
- To protect and enhance recreational, heritage and wildlife spaces, to create healthier and more resilient communities, particularly those with higher inequality or limited access to green space and contribute to ambitions for the Avon Corridor as a key green infrastructure resource.

1.2 Strategic case

Tidal and fluvial flooding from the River Avon represent an increasingly significant risk to Bristol and its neighbouring communities with the potential for severe consequences. The city is at risk from both tidal surges

from downstream and high river flows from upstream. Climate change is increasing sea levels and peak river flows meaning that widespread flooding of central Bristol likely to become a relatively frequent occurrence (Figure 7).

Bristol has a history of flooding. Over twenty minor tidal events in the last decade have flooded properties and/or roads around the river including at Sea Mills, the Portway, Cumberland Basin, Avon Crescent, Coronation Road, Cattle Market Road and at St Philip's, the highest in March 2020.Ble 19
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Flooding currently poses a threat to lives, properties, wellbeing and the long-term economic prosperity of the city and wider region. A severe flood today would result in lasting widespread impact from hazardous flood water, damage to property, damage and disruption to infrastructure and loss of cultural heritage.

Bristol's Floating Harbour forms a fundamental part of the city's current River Avon flood defences. The harbour's capacity is limited and the tidal flood gates are increasingly vulnerable to operational failure, overtopping and outflanking by flood water.

Futureproofing the city and neighbouring communities – Without investment, Bristol and neighbouring communities are at increasing risk of widespread flooding. Around 1,100 homes and businesses near the city centre and 200 properties in neighbouring communities are at risk of being flooded in either a severe river or tidal flood today from the River Avon. Tidal flooding would be relatively rapid. Predictions show flood waters inundating a wide area to significant depths, creating an environment hazardous to life. Without action, by the end of the century almost 4,500 existing properties could be at risk in severe floods (Table 1).

Figure 2 Visualisation of flood risk predictions looking east – Hotwells and Junction Lock in foreground, SS Great Britain and Spike Island in background

Figure 3 Visualisation of flood risk predictions looking east – Temple Meads in foreground, St Philip's Marsh and Netham in background

Year	Location	Residential properties	Non-residential properties	Total
2025	Central Bristol	510	615	1,328
	Downstream	129	40	
	Upstream to A4174	22	12	
2125	Central Bristol	2253	1880	4,459
	Downstream	223	51	
	Upstream to A4174	32	20	

Table 1: Properties at risk of flooding in 0.5% AEP tidal or 1% AEP fluvial events in the Do-Minimum status quo baseline (Note this avoids double counting and is not properties claimed in the Partnership Funding Calculator)

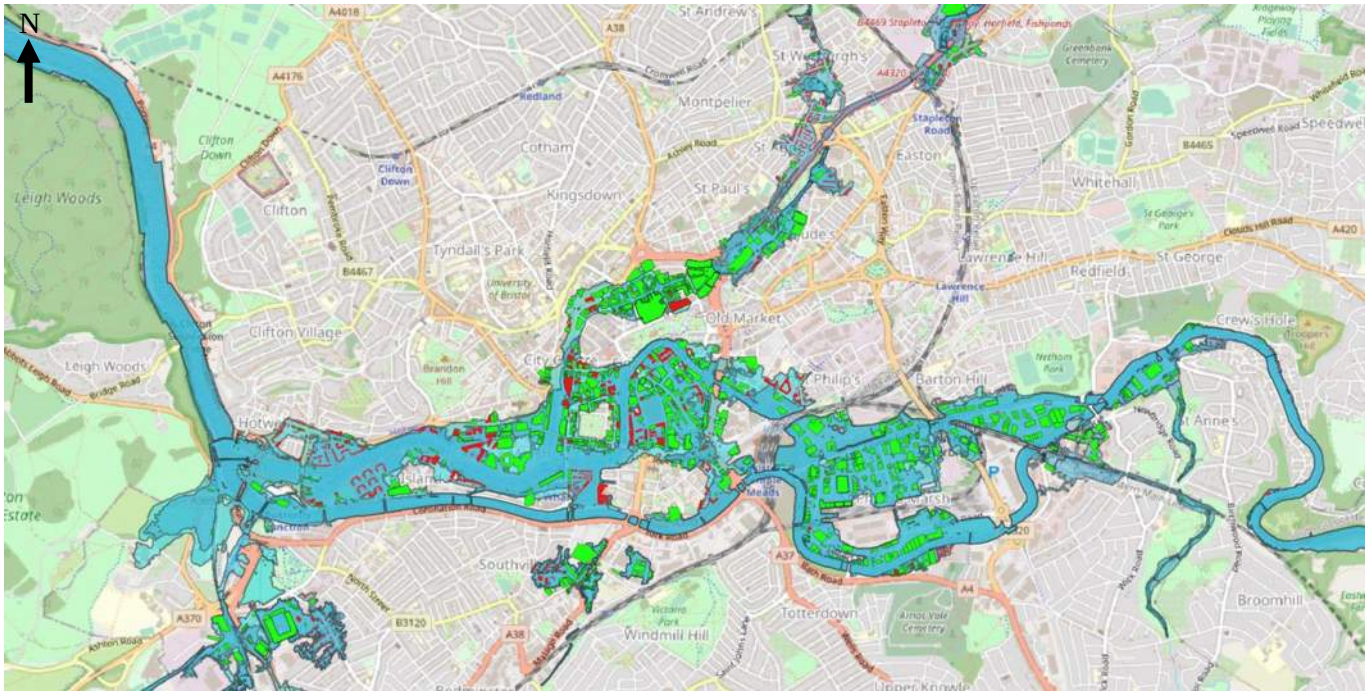


Figure 4: Plan showing central Bristol with points identifying residential (red) and non-residential (green) properties with either greater than a 1 in 200 tidal (pale blue extent) or greater than a 1 in 100 fluvial (dark blue extent) annual chance of river flooding, with allowance for the impact of climate change to 2125.

Without investment, Bristol and neighbouring communities are at increasing risk of widespread flooding.

Enabling a greener, more active city – Creating and improving flood defences presents an opportunity to improve walking and cycling routes along the River Avon. Links could be created with other parts of the city, better connecting people with housing, work and recreation. Improved active travel links could be integrated into the defences. In areas where more space is available, defences could take the form of a green space that provides additional wildlife and recreation benefits every day. Access to the riverside could be improved, whilst areas with historic features, such as retaining walls, could be restored and maintained to prolong their life.

Unlocking Bristol's potential - Currently, without a Flood Risk Management Strategy that has reasonable certainty of delivery, new development must individually deliver flood risk mitigation to ensure the development is safe for its lifetime (100 years for residential uses) without increasing flood risk elsewhere and benefits from safe, dry access during a "design flood". In some locations this is extremely challenging to achieve, meaning development is unlikely to comply with national planning policy and may be refused on this basis. Hence, regeneration in the area is stagnating. The proposed approach has learnt lessons from other cities divided by rivers who have successfully seized similar opportunities including Derby, Leeds and Sheffield.

A Strategy with a reasonable certainty of delivery will reduce the constraint of flood risk and open opportunities for regeneration and new development, contributing to the economic success of the city. By defending areas currently at risk of flooding, the proposed defences would also unlock wider benefits to the city through supporting growth and regeneration such as the jobs, homes and public spaces that will ensure Bristol is a resilient city where people and business can thrive.

1.3 Economic case

The preferred long-term adaptive approach is to create new flood defences or raise the level of existing flood defences in phases along sections of the River Avon riverbanks to better protect people and property from the increasing risk of flooding from the River Avon.

The Strategy will deliver an estimated **£980m in benefits to the UK economy by reducing flood risk** over the next hundred years ("Outcome measure (OM)1a benefits"). These benefits include £118m benefits to people (OM1b) and 553 properties at flood risk today are moved to a lower risk band by the end of the strategy life (OM2a). A further 28 that would have become at risk by 2040 due to the impact of climate change are also moved to lower risk bands (OM2b). **The benefit to the local economy could be over £7.7bn.**

The operation of the existing infrastructure around the Floating Harbour reduces tidal flood risk. However, this will become less effective in future due to climate change, and there is an increasing risk that this will not be able to be operated during large flood events.

A comprehensive appraisal process of strategic approaches has been carried out to determine the preferred way forward to manage flood risk over the next hundred years. Different flood defence techniques that might be effective were identified. Combinations of these techniques were used to create a long list of adaptive approach options. This was reduced to a shortlist from which the preferred approach of phased raised defences was selected as the most feasible option for reducing the flood risk to Bristol and its neighbouring communities.

Discounted flood defence techniques include:

- Source techniques to **slow the flow upstream** to reduce the peak flow (such as flood storage, working with nature or land management) were discounted on technical grounds due to the impractically large scale of required upstream works and the fact that this approach would not reduce tidal flooding from the estuary.

- Source techniques which **keep out tidal surges** include tidal barrages (permanently damming the river and controlling water levels upstream, such as the Cardiff Bay barrage) and tidal barriers (closes at times when flood tides are forecast, such as the Thames Barrier in London). A tidal barrier would be significantly more expensive than the preferred approach. A barrage would be even more costly than a tidal barrier and would have significant negative impacts on habitats, landscape, fish passage and navigation of the river. Both a barrage and barrier were found to increase upstream flood risk as the River Avon does not have enough space to store river flows trapped when the barrier is closed. Potential for wider benefits to be incorporated into a barrier solution (e.g. transport links) were considered but this failed to improve the economic case.

- Pathway techniques to **increase the river flow conveyance capacity** (such as dredging or constructing a flood relief channel or tunnel) could potentially reduce fluvial flooding however these have been discounted as they would increase tidal flood risk by allowing more water to flow up the river from the estuary and space is constrained. **Storing the flood water** in the Floating Harbour as it overtops low spots along the River Avon, with levels lowered at times when flooding is forecast. There is not enough storage space in the harbour and it would be overwhelmed during a severe flood.

- Receptor **resilience** techniques can increase the capacity of people, property and the environment to withstand the impacts of flooding and to rapidly recover after a flood (such as flood plans, flood doors and flood resilient buildings). These techniques are effective for minor flooding but the scale, depth and speed of predicted flooding is too great to rely on these on their own.

The option selection process also identified an adaptive approach (rather than a precautionary approach) had significant advantages in terms of economic efficiency and environmental impact. Defences will be built in phases:

- In the 2020s, raised defences in locations along the Avon from Swineford upstream, through Bristol city centre and as far downstream as Shirehampton and Pill.
- In the 2060s, where necessary these defences will be raised, as well as additional defences being constructed along the Malago, in Totterdown and as extensions to defences already built.

Subsequently, additional analysis was undertaken to determine the required Standard of Protection for the defences in each phase and for the spatial extent of the Strategy.

The preferred scheme on economic grounds in accordance with the FCERM Appraisal Guidance Decision Rule is a 1 in 75 annual chance standard of protection, constructed in 2025 with an allowance for climate change to 2065, and uplifted in 2065 to have a climate change allowance to 2125. This scheme is assessed in the Defra Partnership Funding Calculator to be eligible for £68.5m Grant in Aid funding towards up-front costs.

Local Choice – BCC's local preference is a scheme that unlocks development potential by addressing the requirements of the National Planning Policy Framework (NPPF) to enable development. If such a scheme was also developed in two phases like the Decision Rule compliant scheme described above, the second phase would be very similar to the 2065-2125 phase of the Decision Rule compliant scheme, but somewhat lower in the first (2025-2065) phase. It is therefore recommended that local choice should seek to promote a scheme that provides the highest defence level required by either scheme in each Phase.

The scheme capital costs are estimated at £216m for the initial construction in 2025, which shows that the scheme will fall considerably short of a robust "Partnership Funding" score, and will require significant partnership funding contributions. In the course of strategy development, a number of funding sources have been identified with the potential to meet this requirement.

The whole life costs of the scheme are estimated at £249m present value, which includes an additional £9m present value for the future works in 2065, and maintenance costs of £24.3m. The benefit cost ratio for this scheme (against Grant in Aid eligible benefits) is 4.0 – with details of the alternatives shown in Table 2.

	Do nothing	Do minimum	75yr SoP	100yr SoP	200yr SoP
Damages (PV £m)	1046	886	66	65	52
Benefits (PV £m)	0	160	980	981	994
Whole Life Costs (PV £m)	0	19	246	249	257
Benefit Cost Ratio	-	8.4	4.0	3.9	3.9
ICBR to next option	9	3.6	0.3	1.6	-

Table 2: Present Value damages, benefits and whole life costs of baseline and do-something options of Standard of Protection (SoP) considered by economic appraisal.

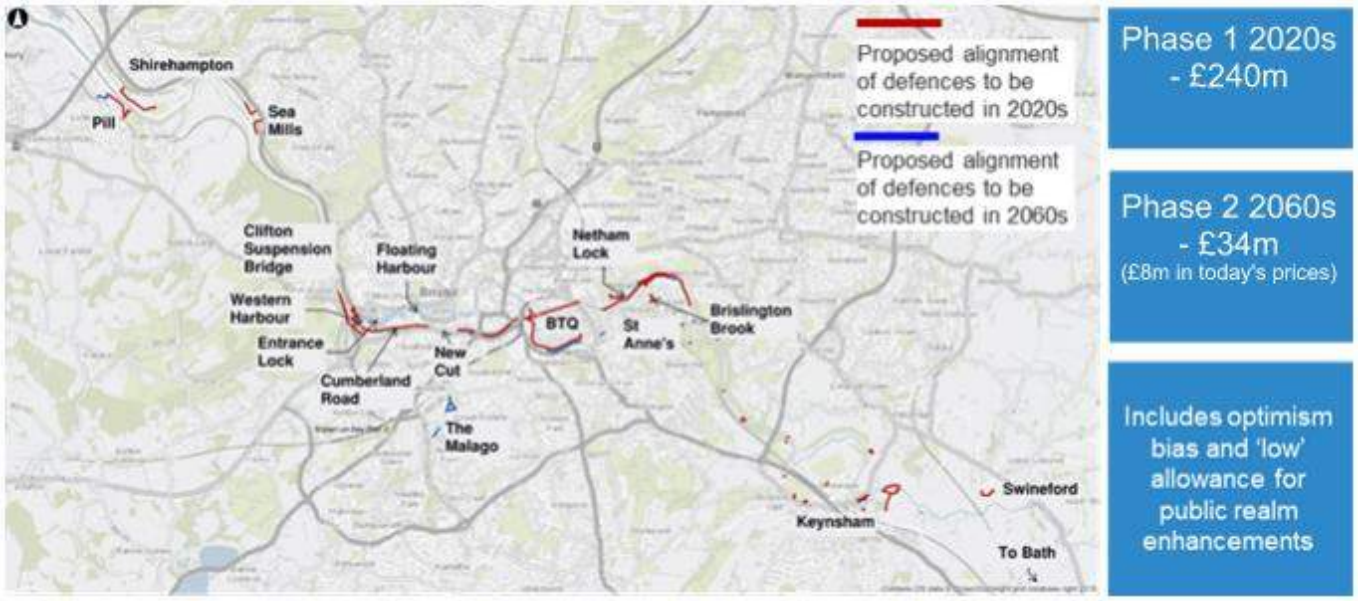


Figure 5 Extent of Defences and total cost of works (maintenance plus capital)

Bristol City Council chose to subject the plans to Strategic Environment Assessment on a voluntary basis to better understand any impacts of the proposed strategy. The SEA recognises beneficial effects on people, health, material assets, heritage features and climatic resilience. The proposals are crucial to the preservation of key areas of Bristol that are fundamental to the character and make-up of the city and will better protect these areas from flood events arising from both tidal and fluvial events. It is recognised that the SEA identifies a number of negative effects through the implementation of the Strategy. Further subsequent detailed studies should be undertaken to further develop the design to minimise the impact on the environment and identify suitable mitigation measures.

1.4 Commercial case

Proposals are at a very early stage. Engineering surveys, engagement and design would be needed before the details of the flood defences can be finalised.

BCC will lead the delivery of the Strategy in recognition of the potential impact and opportunity for the city, and the Strategy's interface with BCC's harbour, highway, planning, lead local flooding, coastal protection, civil protection and major landowner roles. The Environment Agency intends to delegate statutory powers for flood risk management works to Main Rivers to BCC, as necessary.

Procurement for the schemes will first involve the development of Outline Business Cases (OBCs) and then the detailed design, associated surveys and investigations; construction and supporting specialist advice and expertise to successfully manage a major capital project.

There is significant opportunity for coordinating the Strategy with areas of growth and regeneration. The Strategy will be embedded into relevant planning policies and guidance including residual risk mitigation measures to be addressed in planning applications. Integrating defences into development will be encouraged through the publication of local planning guidance setting out expectations of how development should integrate flood defences into proposals.

There are a number of different routes to market that are capable of delivering the needs of the scheme. These will need to be considered at the next stage.

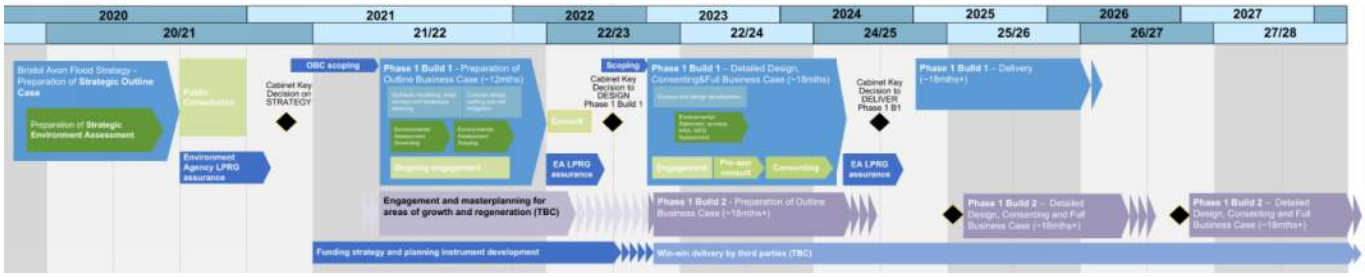


Figure 6: Indicative Strategy delivery timeline showing delivery of Phase 1 Build 1 and Phase 1 Build 2 stages over the 2020s.

1.5 Financial case

The Strategy proposals will rely on funding from a range of sources. **The calculated present value FCERM Grant in Aid (GiA) is £68.5m,** and is specifically for up front capital costs, which means that present value £181m will need to be found through partnership funding sources to fund the present value whole life costs of the scheme (£249.3m), and £147.5m of that will need to be sourced in the immediate future to fund the Phase 1 capital works.

FCERM GiA does not cover maintenance and operational costs. The Strategy assumes the continued maintenance of the existing Floating Harbour and New Cut retaining walls. In general, the Strategy is dependent on the continued serviceability of some of these structures. In practice, a significant part of the projected maintenance and operational costs for the Strategy are derived from the need to continue Floating Harbour operations and these costs would have been incurred anyway.

During Strategy development, several funding sources have been identified.

- The Local Enterprise Partnership's Economic Development Fund has a programme allocation of £5m (2023) and £5m (2032).
- BCC has funded the £9m 2020 Cumberland Road Stabilisation Works, required to deliver the flood defences, by prudential borrowing under the Approved Capital Programme. This will be evidenced and claimed as partnership funding.
- The other potential capital sources include the West of England Combined Authority programme and Community Infrastructure Levy, and private development cash/in-kind contributions.

Opportunities for contributions in the form of cash or 'in kind' contributions such as associated works delivered by BCC or developers will be sought. The economic analysis identifies significant potential benefits (£7.7bn) to the local economy, in terms of supporting development proposals, protection against business disruption, the tourism economy, and transport infrastructure improvements. With a clear plan for managing the risk of River Avon flooding, businesses can have confidence that Bristol is a city to invest in, helping in turn to fund defences for the city and ensuring flood defences are integrated into new developments.

1.6 Management case

Future stages of the Strategy including OBCs, detailed design and construction will be overseen by a multi-agency Project Board. The Board will comprise senior management representation from BCC, the Environment Agency and supplier(s), and will be supported by a project team led by a dedicated Project Manager. The Strategy will be reviewed periodically over its lifetime, at least every twelve years or as the evidence base is significantly updated.

The Strategy will be delivered using powers under the Flood and Water Management Act or Water Resources Act. BCC is the landowner for the majority of the Strategy however in St Philip's, east of Temple Meads and in neighbouring communities there will be third-party interfaces.

In Autumn 2020, public consultation is planned to inform BCC's decision-making prior to adopt the Strategy. The consultation will raise awareness of the need for the Strategy and seek views on the leading strategic approach. BCC will work with neighbouring authorities to consult the communities affected by the proposals outside of Bristol. The Strategy will be submitted to the Environment Agency for endorsement, following Large Project Review Group (LPRG) assurance.

Next steps for the Strategy include:

- A carbon assessment appropriate to the level of design will be completed to support Environment Agency assurance of the Strategy.
- Work with funding specialists to develop a detailed funding strategy.
- Development of planning instruments to support the implementation of the Strategy.
- Additional numerical modelling, including refinement upstream and downstream of Bristol and more detailed modelling to investigate flow pathways between flood sub-cells in high magnitude flood events.
- Additional refinement of the defence designs and alignments when developing OBCs for any of the phases that follow on from the Strategy
- Further consideration to maintenance aspects including assessment on a site by site basis.
- Further consideration of environmental mitigation and net gain enhancement such as landscaping, public realm and habitat improvements.
- Environmental scoping and consenting – i.e. EIA, HRA, WFD.
- Further investigate opportunities and enhancements in relation to the Strategy with regards to heritage, environmental and cultural outcomes, interfaces with the Harbour asset management, and areas of growth and regeneration.
- Refinement of scheme costs and benefits.

To better protect people and property from the increasing risk of flooding from the River Avon, the preferred long-term approach is to create new flood defences or raise the level of existing defences in phases along sections of the riverbanks.

Summary of key benefits of the Strategy:

Future-proofing: Nearly 4,500 properties better protected against flooding in Bristol and the surrounding areas over the next 100 years, with £820m of benefits to the economy

Adaptive: Mitigate climate change and sea level rise with sufficient flexibility to progressively improve flood risk management

Supporting development: Reduce the constraint of flood risk and open opportunities for regeneration and new development, contributing to the economic success of the city

Environment: Provide beneficial effects to people, health, material assets, heritage features and climatic factors, as well as opportunities for environmental enhancement and biodiversity net gain

Strategic Case

Why is a flood strategy needed?

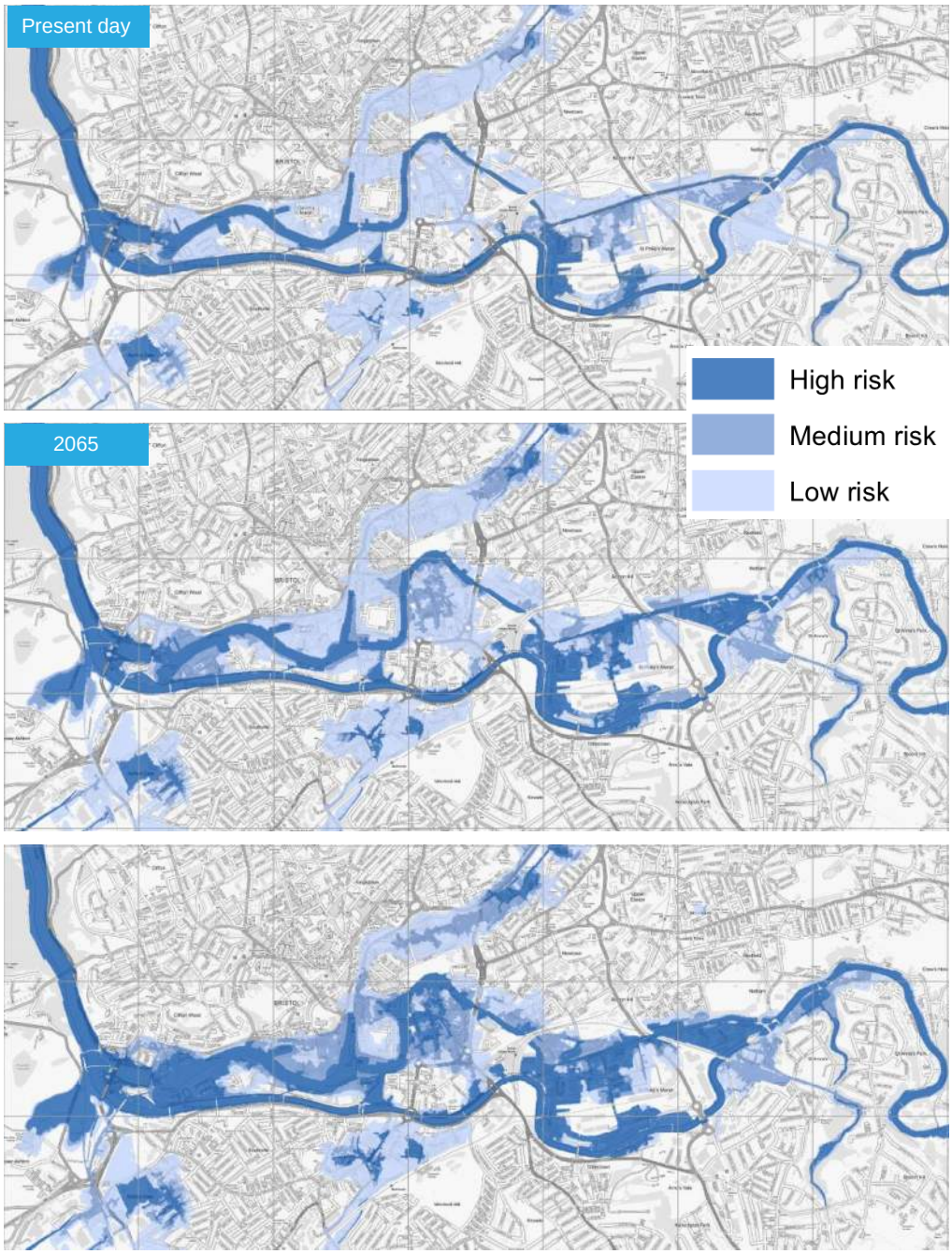


Figure 7: Flood threat today (top) increases significantly with the impact of climate change (bottom)

2 Strategic Case

2.1 Introduction

Bristol and its neighbouring communities have grown and thrived on the banks of the River Avon, creating one the largest economic centres in the South West.

Figure 8 View of Entrance Lock from downstream

Built on a background of trade, commerce and infrastructure, Bristol has grown into a city recognised internationally with a sustainable, innovative and culturally diverse community. The city's success brings with it challenges such as inequality, increased cost of living and congestion.

As with any city located close to rivers and the sea, Bristol has experienced many flood events in its past. Today its people and property face an ongoing flood threat which due to climate change will significantly worsen in future without intervention. In addition, it is becoming increasing difficult to enable development to proceed within the city centre under the current circumstances, stagnating the city's ability to thrive.

A Strategy for flood risk management is needed to better protect Bristol and neighbouring communities from the increasing flood risk posed by the River Avon from high river flows and tidal surges. A major flood event which currently has a 0.5% (1 in 200) annual chance of occurring now, could occur as frequently as once a year by the end of the century if no strategic management of the risk is implemented.

The Strategy is ambitious and will rely on funding from a range of sources. With a clear plan, flood defences can be integrated with high-quality public spaces in future developments, positively regenerating areas around the River Avon, whilst giving businesses the confidence to invest in Bristol, unlocking the funding needed to realise these ambitions.

2.1.1 The Bristol Avon flood strategy background

The Bristol Avon Flood Strategy sets out a strategic long-term plan for managing flood risk from the River Avon to Bristol and its neighbouring communities.

The Strategy has been developed by Bristol City Council (BCC), with support from the Environment Agency, and consultants Arup and AECOM. BCC lead in recognition of the potential impact and opportunity for the city, and the Strategy's interface with BCC's harbour, highway, planning, lead local flooding, coastal protection, civil protection and major landowner roles. The Environment Agency will play an essential role given their statutory lead role for Main River and coastal flood risk management.

This report is presented in the format of a Strategic Outline Case (SOC). The report is intended to inform BCC's decision makers and will be formally submitted to the Environment Agency to support advancing the first phase of the Strategy. Submission will follow formal public consultation and further engagement with statutory consultees.

2.1.2 Flood risk

The strategy has been developed because effective strategic flood risk management is essential for the long-term sustainability of Bristol and the health and wellbeing of its citizens, as well as neighbouring communities. Flooding poses a threat to lives and property, and to the long-term economic prosperity and viability of the city.

Bristol is positioned near the mouth of the River Avon as it connects with the Severn Estuary, with the second highest tide in the world. It is therefore subjected to flood risk caused by extreme tidal events (from the sea) and extreme fluvial events (from the inland waterways) and probabilistic combinations of both types of events occurring at the same time.

The predominant flood risk and potential for the most severe damage to much of the city centre is from high tides combining with storm surges. This forces water up the river, overtopping many low spots around the harbour and causing the Floating Harbour to flood properties.

Around 1,100 homes and businesses near the city centre and 200 properties in neighbouring communities are currently at risk of being flooded in either a severe river or tidal flood from the River Avon, severing the region's transport network (see 2.2.1), causing grid lock to the city centre, and putting the operation of the existing flood risk management systems at risk.

2.1.3 Influence of climate change

Since 1900, UK sea levels have risen by more than 16cm. Studies of records at Avonmouth found between 1993 to 2007 sea levels on average increased 0.2cm every year. As a consequence of climate change, the observed increasing sea levels and peak river flows are predicted to continue and accelerate. Without action, by the end of this century over 4,400 existing properties could be at risk in the event of a severe tidal flood. Figure 9 shows the areas that would be flooded by a 1 in 2 annual chance flood in 2065 and 2125 should no action be taken (the 'Do Nothing' scenario). The 2125 flood outline is the equivalent of a 1 in 200-year event today.

Flood risk is currently a significant constraint on development opportunities in central Bristol. Without a strategic intervention, the predicted impact of climate change would exacerbate the impact of flood risk and further constrain the scale and form of development in the central area.

Flood risk in the study area will increase unless appropriate action is taken. BCC operates the infrastructure in the Floating Harbour which forms a fundamental part of the flood defences of the City. However, this is increasingly vulnerable to tidal overtopping.

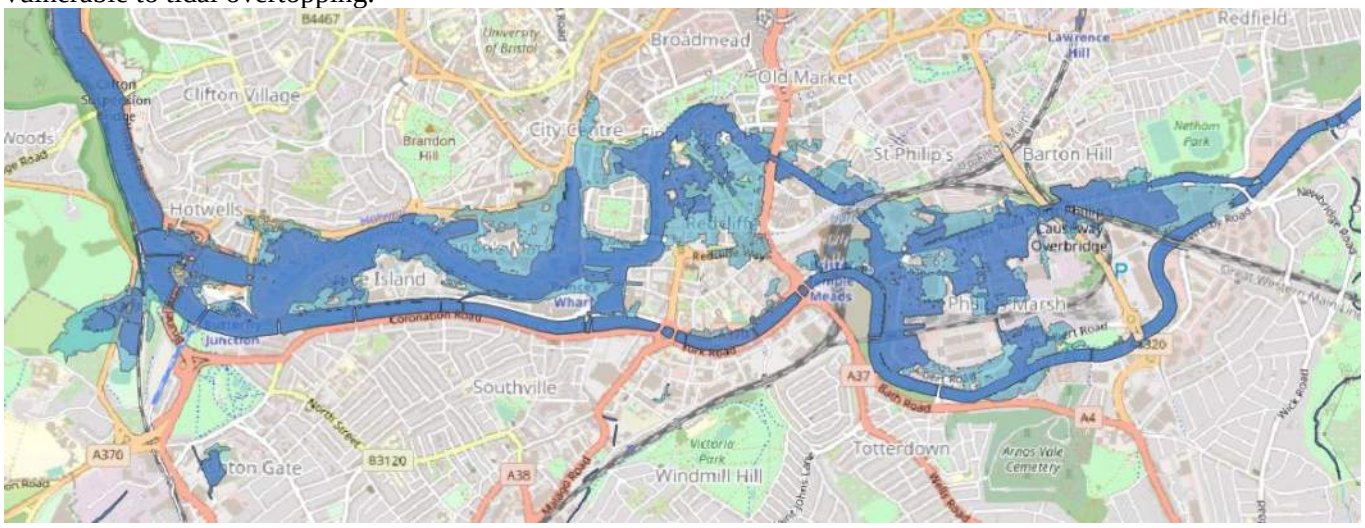


Figure 9: Do Nothing 1 in 2 annual chance tidal flood outline, 2065 (dark blue) and 2125 (light blue).

Two different climate change allowances have been used in this study:

- NPPF: This has been used to determine the scale of raised defences that would be required for new development to meet NPPF requirements if other mitigation such as ground raising was not undertaken. It has also been used for the assessment of residual flood risk, to assess any adverse impacts from the proposed Strategy option and to determine the scale of works to prevent adverse impacts. The Environment Agency have advised that the higher central band for fluvial flows is used for new residential developments.

- FCERM: Guidance for Risk Management Authorities has been used to determine the crest level of all other raised defences. For fluvial flows, the Central allowance is used. For relative sea level rise, the UKCP09 medium emission 95% projection data is used. FCERM defence levels are those levels set by climate change

allowances for risk management authorities (as opposed to those levels set by climate change allowances for planning, NPPF levels).[1]

2.1.4 Strategy development

In 2017 an early study focusing on the threat from tidal surges was produced. The River Avon Tidal Flood Risk Management Strategy (the "2017 Study")[2] was developed by BCC with consultants AECOM following the Environment Agency's strategic appraisal approach whereby the technical, economic, environmental and social merits of a range of strategic options were assessed. The 2017 Study set out a preferred option which involved delivering flood defences at low spots along the River Avon delivered in phases. Engagement was limited to statutory consultees informing the emerging technical studies. The 2017 Study is referred to throughout this document.

In 2018 Arup were appointed to work with BCC to develop the 2017 Study, the results of which are set out in this document. The work reviews and builds on the evidence base and ensures that the strategic approach also manages fluvial flood risk and delivers wider benefits to public spaces. Following discussions with members of LPRG, this report is presented in the format of an SOC.

The revised Strategy adds detail in considering:

- combined fluvial and tidal flood risk
- future areas of growth and regeneration around the harbour and NPPF requirements
- opportunities to unlock wider benefits of the Strategy
- measures to prevent adverse impacts of the preferred option
- a revised phasing plan
- updated costing and economics
- updated funding strategy
- the environmental impact of these options, in addition to the work done as part of the 2017 Study
- a plan for stakeholder engagement.

2.1.5 Historic flood events

Bristol has a long history of flooding, as suggested by numerous place names throughout the city centre, such as Temple Meads and St Philip's Marsh. The extent of tidal dominance in the New Cut channel changes depending on tide conditions. Under extreme conditions the tide can extend far upstream of Netham Weir.

Bristol has been lucky in recent years and has avoided severe flooding. However, there have been more than twenty minor tidal floods in the last decade. Properties and/or roads around the river have been flooded including at Pill, Sea Mills, the Portway, Cumberland Basin, Avon Crescent, Coronation Road and Cattle Market Road.

A 1.6m tidal surge in December 1981 caused levels to reach 8.8mOD and flood many properties at Pill, Shirehampton, Avon Crescent and across St Philip's. Subsequently flood defences were constructed by the Environment Agency at Pill, Shirehampton and St Philip's. Despite this defence, there was still localised flooding of St Philip's in 2014 and 2020.

There have been many recent near misses. Levels reached 8.8mOD in February 1990 and 8.7mOD in January 2014 when flooding closed key roads including the A4 Portway, Cattlemarket Road and Cumberland Road. Good weather in 2014 reduced forecast surge levels by 0.8m and the proactive use of a temporary barrier protected properties at Avon Crescent.

[1] Following completion of all hydraulic modelling for the SOC, FCERM climate change guidance was updated in 2020. The allowances for fluvial flow increases are unchanged, but the sea level rise allowances are greater and comparable with NPPF allowances. The latest climate change guidance should be considered in modelling for future stages.
[2] AECOM, "River Avon Tidal Flood Risk Management Strategy - Strategy Technical Report," 2017.

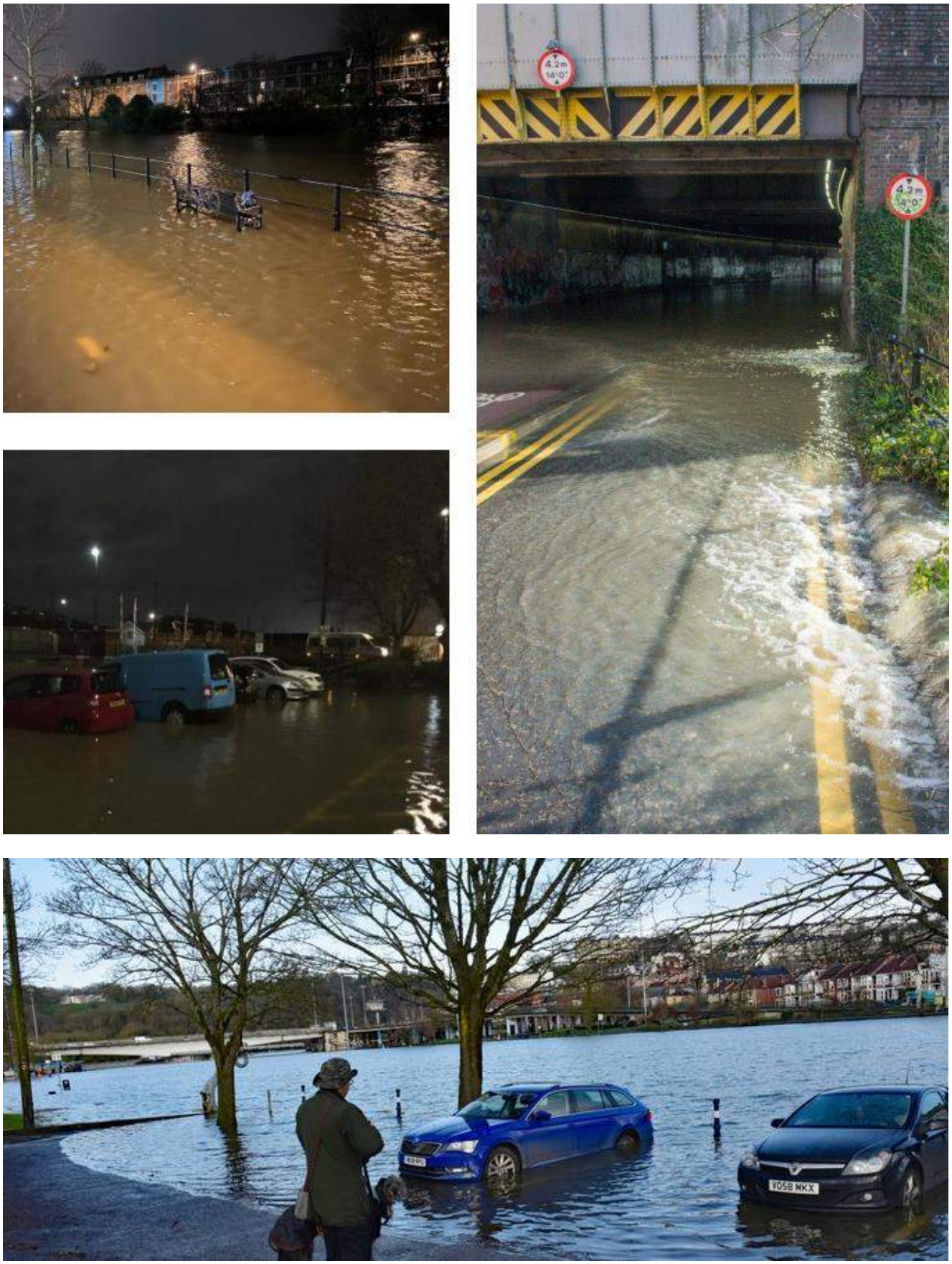


Figure 10: March 2020 tidal surge caused localised overtopping around the Harbour and River Avon

In March 2020, Bristol experienced the highest tidal event (of 8.81m AOD) since records began. This led to significant flood depths under the Clifton Suspension Bridge, at Junction Lock and at Cattle Market Road (see Figure 10) . Flooding occurred for up to 15 hours[3]. Astronomical high tides combined with a 1.0m storm surge caused by a low-pressure system and south-westerly winds. Flood gates were closed at Pill and Shirehampton. At Sea Mills property flood defences were successful in protecting all but one property. Roads were inundated throughout the city, with disruption amplified due to precautionary closures for safety. The following morning, levels were again high at 8.67mOD. It was also difficult to access the harbour assets for maintenance and proactive intervention as the harbour side itself was flooded. The event could have been significantly worse if it had coincided with the worst of the storm surges seen just a few weeks earlier.

Downstream, Pill and Shirehampton experienced widespread flooding with three major tidal flooding episodes between 1981 and 1990 affecting roads and properties to depths of 0.6m, prior to construction of raised defences. The riverside communities here have a long history of fluvial flooding.

Upstream, high tides frequently overtop Netham weir. The tidal limit stretches up to Hanham Weir in a 50% fluvial event with a MHWS. However, a 1 in 200 (0.5%) Annual Exceedance Probability (AEP) tidal event paired with a 50% AEP fluvial event impacts almost to Saltford Weir because the tide prevents fluvial flows from discharging.

2.1.6 Extent of Strategy Influence

Outside of Bristol, the Strategy extends into North Somerset at Pill and Ashton; South Gloucestershire at Hanham; and Bath and North East Somerset (B&NES) at Keynsham, potentially interfacing with emerging ambitions for growth and regeneration at North Keynsham.

2.2 Need for intervention

The ‘Do Minimum’ scenario for this Strategy represents a continuation of the status quo, assuming existing activities are continued and the current defences are kept in place, but not raised. The do minimum scenario is described in more detail in 3.5.6, as it also takes into account the fact that the infrastructure must be operated successfully, which is in itself susceptible to potentially hazardous flooding.

Numerical modelling has shown that around 1,100 homes and businesses near the city centre and 200 properties in neighbouring communities are at risk of being flooded in either a severe river or tidal flood today from the River Avon in the strategy area and sever the region’s transport network. Tidal flooding would be relatively rapid. Predictions show flood waters inundating a wide area to significant depths, creating an environment hazardous to life. Without action, by the end of the century almost 4,500 existing properties could be at risk in severe floods.

Year	Location	Residential properties	Non-residential properties	Total
2025	Central Bristol	510	615	1,328
	Downstream	129	40	
	Upstream to A4174	22	12	
2125	Central Bristol	2253	1880	4,459
	Downstream	223	51	
	Upstream to A4174	32	20	

Table 3: Properties at risk of flooding in 0.5% AEP tidal or 1% AEP fluvial events in the Do-Minimum status quo baseline (Note this avoids double counting and is not properties claimed in the Partnership Funding Calculator)

[3] Bristol City Council, “Flood Investigation for the March 2020 Tidal Flood Events,” 2020.

The main areas of River Avon flood risk in central Bristol are located on the north bank of the New Cut and the Floating Harbour. On the south bank of the New Cut the flood risk is more localised and often multi-sourced, for example, from tide locking of fluvial watercourses. Flood maps showing the flood risk to Bristol in a 'do nothing' or 'do minimum' (the status quo) are included in Appendix B.

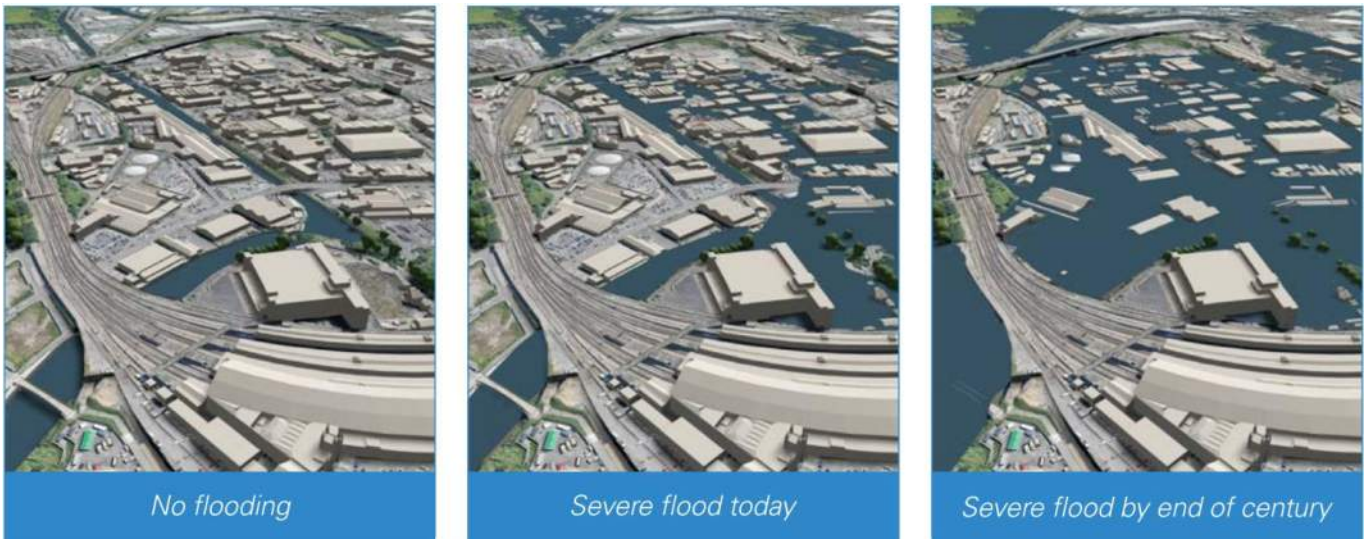


Figure 11: View looking East - Temple Meads in foreground, St Philip's Marsh and Netham in background

Figure 12 View looking east - Hotwells and Cumberland Basin in foreground. SS Great Britain and Spike Island in background.

The impact of widespread flooding to Bristol would be felt across the West of England due to the city's importance for employment, transport, recreation, tourism and economic growth. Key heritage and tourist attractions are also at risk, such as the SS Great Britain (located in the Floating Harbour), the Mshed and We the Curious museums.

2.2.1 Transport severing

Bristol is a South West hub for links between South East (Bath, Swindon, Reading, London), the Midlands (Gloucester, Cheltenham, Birmingham), Wales (Cardiff, Newport) and the South West (Bridgewater, Exeter, Devon Cornwall). Many people work, visit or travel throughout the centre of Bristol every day, so people across the city and the region will be affected. Although it should be noted that the coronavirus pandemic may have a long-term effect on transport and how people use cities, the centre of Bristol will remain vital. Bristol's transport network is vulnerable to flooding; ranging from the Portway and riverside arterial routes to Bristol Temple Meads railway station underpass (a key transport hub for the wider south-west region) becoming impassable.

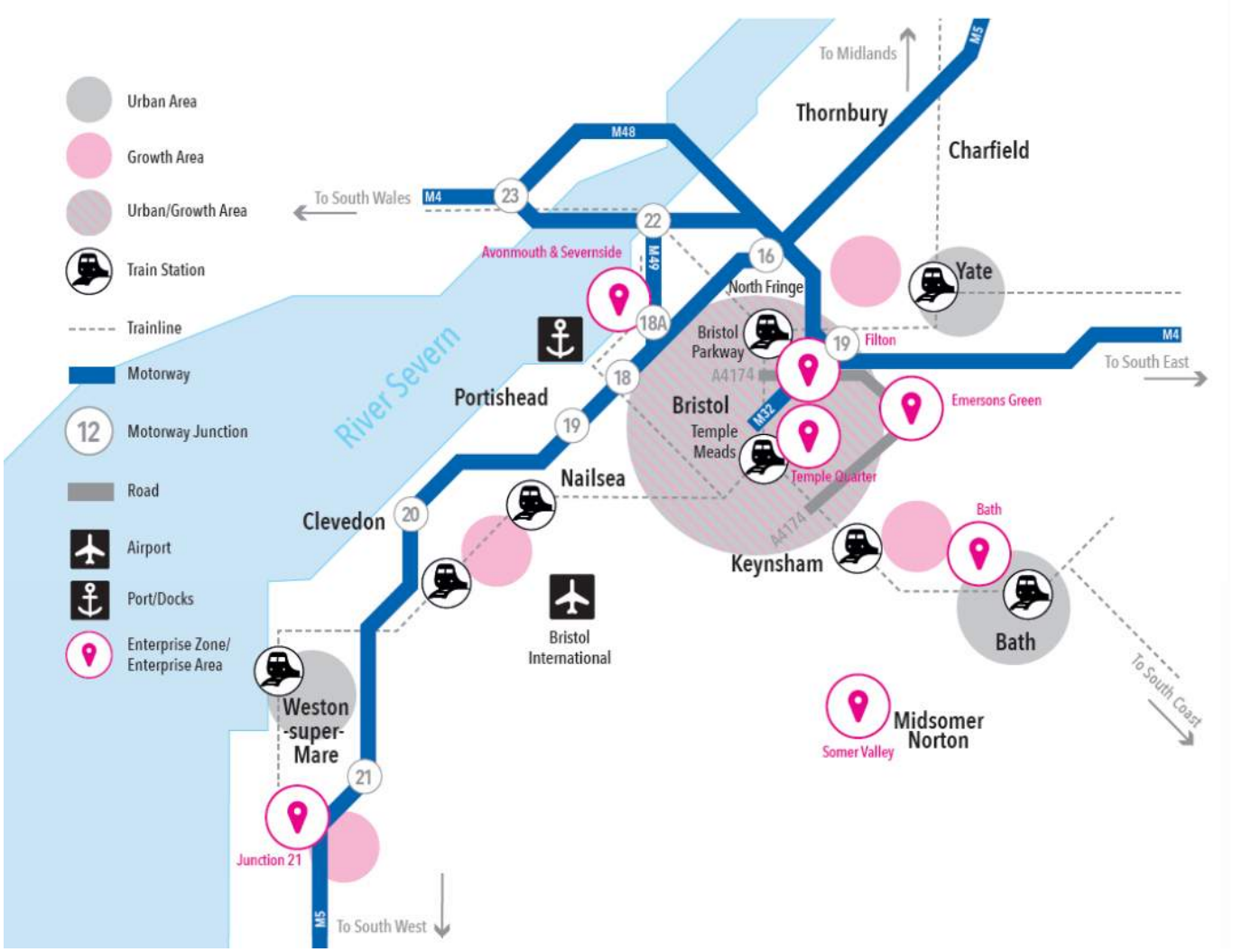


Figure 13: Bristol is a key transport hub for the South West and beyond[4]

2.2.2 Social consequence

Flooding can also have large social consequences for communities and individuals. Parts of Redcliffe and Barton Hill fall within the 10% most deprived neighbourhoods in England. In some cases, flooding can lead to poverty in low income households. It can make life more precarious for the vulnerable and elderly and have psychological impacts. There are also both short- and long-term health impacts associated with flooding. For instance, drowning, injuries and hypothermia could all occur during or immediately after a flood event, whereas long term issues such as chronic disease, disability, poor mental health and stress and anxiety related illnesses may be a legacy from a severe flood event.

The benefits of reducing the flood risk in Bristol are therefore wide ranging, with economic, social, health, infrastructure, recreation and tourism benefits.

2.3 Supporting development

Developments in central Bristol which are at risk of flooding must be consistent with the 'sequential approach' and comply with the 'exception test'. That means they should deliver sustainable development benefits which outweigh the flood risk and will be safe for their lifetimes without increasing flood risk elsewhere. Currently, without a Flood Risk Management Strategy that has reasonable certainty of delivery, new development must individually deliver flood risk mitigation to ensure the development is safe, for its lifetime (100 years for residential uses) without increasing flood risk elsewhere and benefits from safe, dry access during a "design flood". In some locations this can be impossible to achieve in some locations meaning development is unlikely to comply with national planning

[4] Western Gateway, "Draft Strategic Transport Plan 2020-2025".

policy and may be refused on this basis, including on some sites already allocated for development in the local plan. In such circumstances planning applications will be recommended for refusal because they would be contrary to NPPF regarding flood risk. Hence regeneration in the area risks stagnating.

Once the Strategy is adopted by Bristol City Council and endorsed by the Environment Agency as having reasonable certainty of delivery (see Section 4.2), it will reduce the constraint of flood risk and open opportunities for regeneration and new development, contributing to the economic success of the city. The proposed approach has learnt lessons from other cities divided by rivers who have successfully seized similar opportunities including Derby, Leeds and Sheffield. Proposed developments in areas currently at risk of flooding are anticipated to be able to rely on planned strategy measures (now and future phases).

2.4 Aligned business strategies

2.4.1 Flood and Coastal Risk Management

The Strategy sits on the second tier of flood risk management hierarchy, below the Severn Estuary Shoreline Management Plan (SMP) which was completed in 2010 and the Local Flood Risk Management Strategy (LFRMS) and Flood Risk Management Plan (FRMP) for Bristol.

These plans and strategies identify flood risk management policies to deliver sustainable flood risk management for the long term. The SMP is a high level non-statutory planning document which presents a long-term policy framework to reduce the risks associated with coastal processes. Within the SMP, the Strategy area has a designated ‘hold the line’ management policy.

In the LFRMS and FRMP the recommended policy for Bristol is to take further action to reduce flood risk to ensure that the standard of protection through Bristol is improved where required. The Wessex Regional Flood and Coastal Committee Strategy identifies Bristol as a priority at-risk community. Managing flood risk is also a priority in Bristol City's Resilience Strategy initiative.

In addition to these plans and strategies a number of studies have investigated flood risk in Bristol in more detail. In 2010 BCC commissioned the Bristol Central Area Flood Risk Assessment (CAFRA) to develop an understanding of flood risk on tidally influenced watercourses within the Bristol City Boundary. A significant aspect of this study involved the building of a numerical hydrodynamic model and its use for option testing. Updates to the CAFRA study were made in 2014, 2015, 2017 and 2019.

In 2013, a First Phase Feasibility study was undertaken to appraise strategic options to manage the flood risk in central Bristol. Given the changing flood risk profile over the next century an adaptive approach that progressively improves the flood risk management by building on the outcomes of previous interventions was advocated by the study.

In addition to the above, a draft of the Severn Estuary Flood Risk Management Strategy has been produced. This defines a 100-year plan of investment for flood defences for the coast between Gloucester to Lavernock Point near Cardiff, and from Gloucester to Hinkley Point in Somerset. The Strategy does not yet have formal approval from the Department for Environment, Food and Rural Affairs (Defra) or the Welsh government and is considered a working draft.

2.4.2 Climate Resilience

The Climate Change Act 2008 commits the UK Government to reduce carbon emissions to net zero by 2050.

BCC declared a Climate Emergency in 2018, recognising the risk of climate change to the city. In 2020 BCC published the Bristol One City Climate Strategy[5] setting out a strategy for a carbon neutral, climate resilient Bristol by 2030. The wider opportunities of flood risk mitigation are recognised, such as integrating green infrastructure

[5] Bristol City Council, “One City Climate Strategy”

solutions into a city centre flood management strategy and developing wildlife and nature corridors (green and blue) to create a network through Bristol that connects to surrounding areas.

Launched in January 2019, the One City Plan describes where BCC want to be by 2050, and how city partners will work together to create a fair, healthy, and sustainable city. Drawing from feedback, input and consultations throughout the year, the City Office produced the second iteration of the One City Plan. Relevant goals include:

- Improve Bristol's infrastructure to protect against flash flooding in high-density areas (by 2026)
- Sustainable urban drainage will span the city and reduce likelihood of localised flooding during wet weather (by 2043)
- The city is fully resilient and able to respond to rising water levels and localised flood risks (by 2048)

The Environment Agency have committed[6] to become a net zero organisation by 2030. FCERM capital projects form a major source of carbon emissions and early consideration of carbon is required to identify solutions that efficiently minimise whole life carbon impacts.

2.4.3 Planning and Development Policy

The NPPF sets out the Government's planning policies for England. Those policies require that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (whether existing or future) – the sequential approach. Where development is necessary in such areas, the development is expected to be made safe for its lifetime, taking into account the predicted impacts of climate change without increasing flood risk elsewhere. Strategic policies for flood risk are expected to take account of advice from the Environment Agency.

The Bristol Local Plan[7] (running to 2026) sets out the development objectives for Bristol. The local plan includes Bristol Council's approach to minimising the risk and impact of flooding in the context of new development. Its spatial strategy is based on a sequential approach whereby priority is given to development of sites with the lowest risk of flooding in the area.

As part of the emerging Local Plan review, it is expected large numbers of new homes and other forms of development will be delivered in central Bristol within the plan period, with scope for significantly greater numbers where the delivery of flood risk management infrastructure can unlock more potential. New development in areas of current and future flood risk will require appropriate flood risk mitigation to ensure it is safe in accordance with NPPF. That potential is focussed particularly in proposed areas of growth and regeneration at Western Harbour, Bristol Temple Quarter and St Philip's Marsh which all include areas at risk of flooding.

[6] https://www.gov.uk/government/news/environment-agency-sets-net-zero-emissions-aim
[7] Bristol City Council, "Bristol Local Plan Review"

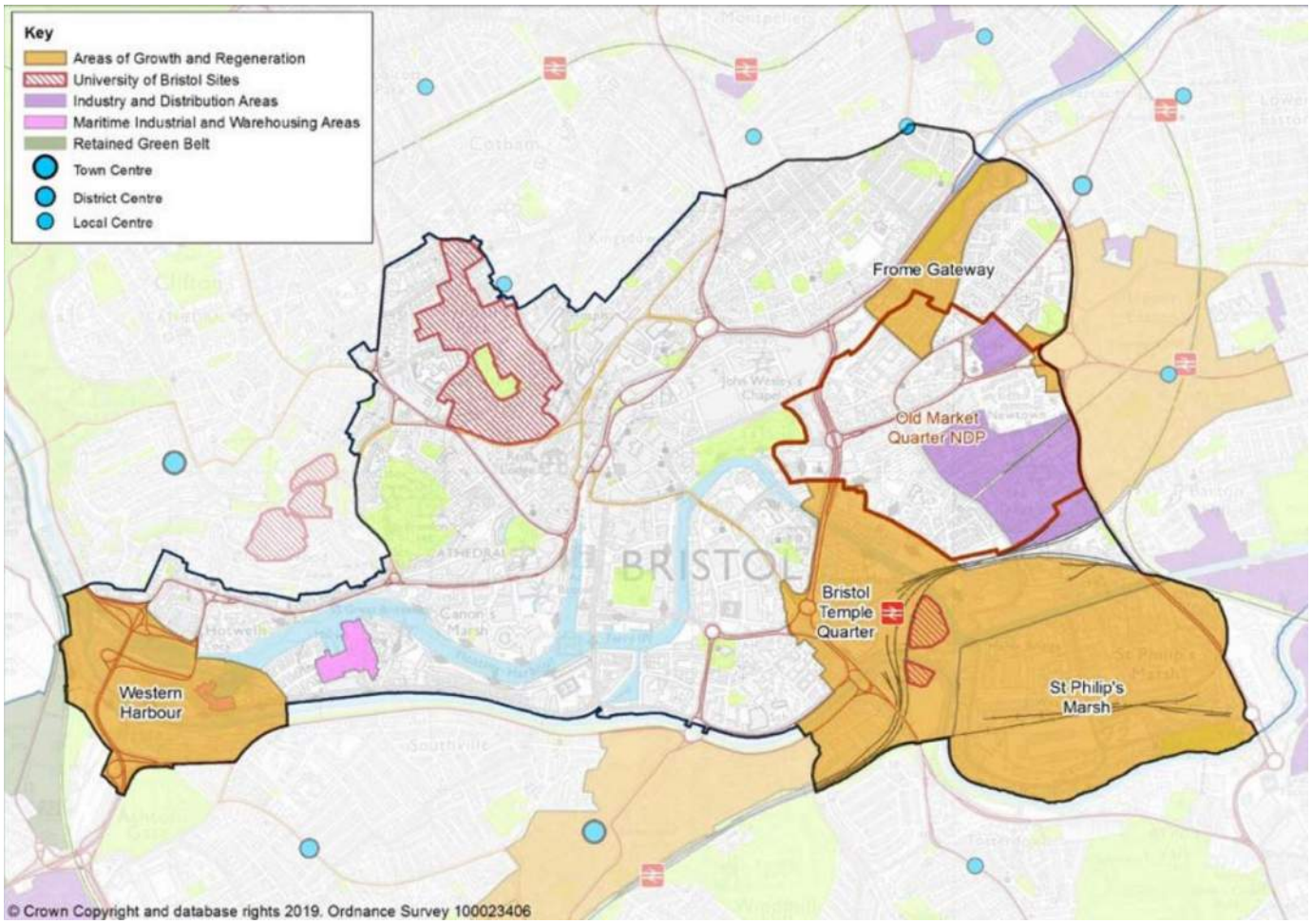


Figure 14: Areas of growth and regeneration identified in the Local Plan Review[8]

2.4.4 Local Cycling and Walking Infrastructure Plan

The spatial extent of the Strategy interfaces with the West of England Combined Mayoral Authority (WECA) regional strategic transport programme, which includes the A4 Bath-Bristol and MetroWest Portishead to Bristol suburban rail corridor enhancements.

In June 2020, WECA produced a Local Cycling and Walking Infrastructure Plan[9] 2020-2036 as part of their wider plans and ambitions for creating and improving active travel, and their vision to *"Connect people and places for a vibrant, inclusive and carbon neutral West of England"*. The plan includes key walking routes and zones, as well as proposed improvements, for several areas impacted by the Strategy including Bedminster, Southville and Shirehampton.

2.4.5 Joint Green Infrastructure Strategy

The West of England Joint Green Infrastructure Strategy 2020-2030[10] aims to secure investment in Green Infrastructure planning and provision. The rich and diverse natural environment of the West of England is integral to the region's health and economic prosperity. Well planned, managed and functioning Green Infrastructure is crucial for people, places and nature and is a key component in addressing environmental impacts including climate change and biodiversity loss. The JGIS strategy establishes the approach for identifying and coordinating future partnership projects and funding bids for key shared GI assets such as the River Avon.

[8] Bristol City Council, "Bristol Local Plan Review"
[9] TravelWest, "Local Cycling and Walking Plan," [Online]. Available: https://travelwest.info/projects/local-cycling-and-walking-infrastructure-plan.
[10] West of England Combined Authority , "West of England Joint Green Infrastructure Strategy 2020-2030," [Online]. Available: https://www.westofengland-ca.gov.uk/west-of-england-joint-green-infrastructure-strategy/.

2.5 Environment and other considerations

2.5.1 Environmental studies

A number of environmental studies have been undertaken throughout the development of the Strategy which have fed into the options appraisal process at key stages. Integral to the development of the preferred strategy approach was the production of a Strategic Environmental Assessment (SEA) in 2017[11]. The Project Board made up of representatives of BCC and Environment Agency chose to commission a voluntary SEA to identify significant positive and negative effects, and ensure the environment was appropriately accounted for within the decision-making process. This comprehensively assessed the proposed flood management approach and evaluated the environmental impacts of different options.

Following submission of the SEA in 2017, BCC commissioned Arup to provide an update given the need to consider fluvial inputs combined with tidal flows to understand broader implications on the core areas of Bristol and the need for flood defences and measures to prevent adverse impacts. An SEA Addendum[12] has been undertaken by Arup that considers the changes to the Strategy as a result of the flood risk modelling undertaken by Arup on the preferred approach and provides an update to the original SEA report to review the environmental impacts to align with the amended Bristol Avon Flood Strategy.

The SEA process coupled with a multi-disciplinary appraisal that was undertaken during the earlier phases of option development has ensured that the environmental implications of the preferred strategic approach have been robustly assessed.

As part of the SEA and the necessary SEA Addendum, preliminary Water Framework Directive Assessment (WFD) and Habitats Regulations Assessment (HRA) have been undertaken to consider the effects of the Strategy in greater detail. As the Strategy develops, it is acknowledged that an Environmental Impact Assessment (EIA) is likely to be required to ensure compliance and that updates to the WFD and HRA assessments should be undertaken. The Strategy will also be subject to planning approval.

2.5.2 Environmental designations

The Strategy area is a mixture of developed urban environment and open space, as well as some agricultural land. There are a number of environmental designations within and adjacent to the study site including:

- Avon Gorge Site of Special Scientific Interest (SSSI), Horseshoe Bend SSSI, Ashton Court SSSI, Ham Green SSSI.
- Avon Gorge Special Area of Conservation (SAC).
- Leigh Woods National Nature Reserve (NNR).
- The Severn Estuary, situated close to Pill and Shirehampton, is designated as a SSSI, SAC, Ramsar and Special Protection Area (SPA).
- The River Avon, which forms a Site of Nature Conservation Interest throughout the city and links Important Open Spaces.

For maps of the environmental designations within and adjacent to the study site refer to the various environmental assessment reports.

2.5.3 Cultural heritage

Given the historic harbourside setting in central Bristol, there are a number of listed buildings, scheduled monuments, conservation areas and locally valued historic buildings that stand to be affected by flooding. These include features important to the heritage of the area including numerous scheduled monuments such as Underfall Yard (within Bristol Docks).

[11] AECOM, “River Avon Tidal Flood Risk Management Strategy - Strategic Environmental Assessment: Environmental Report,” 2017.
[12] Arup, “River Avon Flood Risk Management Strategy - SEA Addendum,” 2020.

There are several Grade I, Grade II and Grade II* listed buildings within the study site, many of which are integral to the existing flood defences along the River Avon and the Floating Harbour and are particularly sensitive to flooding. There are a number of non-designated heritage assets, registered parks and gardens and popular tourism assets including the SS Great Britain and the MShed.

The character of the reaches along the river varies significantly. From the wide-open estuarine environment at Pill and Shirehampton, to the iconic setting of the River Avon gorge, the urban historic townscape of the New Cut, the original river course upstream of Temple Meads with both urban and natural settings, and then to wooded river valley at Conham. The scale of the impact is dependent on the setting of the area and the form and scale of any flood defence.

The River Avon at Entrance Lock (near Cumberland Basin) and Cumberland Road falls within the City Docks Conservation Area. It is rich in both long-range panoramic views, long views to specific features, landmarks and distinctive skylines, as well as short-range contained views and glimpses. The Cumberland Basin area offers high quality views out of the character area including the iconic view of the Avon Gorge and Clifton Suspension Bridge. The Cumberland Road and Bathurst Basin areas are more enclosed, offering local views across the New Cut and longer views along the river corridor to bridge crossings. From Bedminster in the South, when the trees are not in leaf, views from the slightly elevated Coronation Road are across the New Cut to Spike Island, with the distinctive skyline of Clifton, Clifton Wood and Brandon Hill above.

2.5.4 United Nations Sustainable Development Goals

Several of the UN's sustainable development goals are relevant to the development of the Strategy, as described below.

- Goal 8 – decent work and economic growth. The Strategy is required to help to promote economic growth throughout Bristol and its neighbouring communities.
- Goal 9 – industry, innovation and infrastructure. The Strategy is required to ensure Bristol is resilient and has high quality infrastructure.
- Goal 11 – sustainable cities and communities. The Strategy will look to safeguard cultural heritage, reduce the number of people affected by disasters (in this case flooding) and provide access to safe, inclusive and accessible public spaces.
- Goal 13 – climate action. The Strategy will strengthen the city's resilience and adaptive capacity to climate-related hazards and integrate climate change requirements.

Figure 15: Sustainable Development Goals relevant to the Strategy

2.6 Other sources of flooding

Whilst River Avon flooding is the key source of risk being addressed by the Strategy there is also a significant localised flood risk from the River Frome and other tributaries outside the scope of the Strategy. For example at Ashton, where the flood risk from Colliter's Brook is the result of a combination of tide locking, stormwater discharge and land drainage issues.

Other sources of flooding, such as surface water, sewer and groundwater flooding, are outside of the scope of the Strategy and have not been considered in detail. These aspects will need to be adequately appraised and any adverse impacts prevented through suitable mitigation in the design and delivery of required schemes.
Wessex Water (WW), the sewerage undertaker for Bristol, has identified operational performance concerns with a small number of combined sewer overflows into the River Avon, where tidal ingress can occur at times of extreme

high tide. There are reports of drainage surcharging at times of tidal surge. WW plan studies by 2026 to review and improve or rationalise these arrangements where necessary and this may involve pumped arrangements and enhanced non-return valves to maintain flood protection against increasing tidal levels.

2.7 Strategic objectives

The key investment objectives for the Strategy have been set to reflect the importance of delivering robust and sustainable flood risk management infrastructure for the strategy area, whilst acknowledging the importance of the area for employment purposes and future redevelopment opportunities.

- To support the safe living, working and travelling in and around central Bristol by ensuring flood threat is reduced and measures address residual risks.
- To facilitate the sustainable growth of Bristol and the West of England by supporting opportunities for employment and residential land, and infrastructure.
- To maintain natural, historic, visual and built environments within the waterfront corridor and where possible deliver enhanced recreational, heritage and wildlife spaces.
- To ensure navigation of river and marine activities continues.
- To ensure the strategy is technically feasible and deliverable.

In addition, objectives have been developed in relation to placemaking opportunities, following the identification of a preferred way forward. The placemaking opportunities report (Appendix D) expanded on these in relation to the four character areas identified in Figure 16.

- To enhance walking and cycling links to enable greater access to opportunity work and housing.
- To bring existing communities closer together, as well as providing the opportunity to unlock new development land and attract residents, businesses and visitors.
- To protect and enhance recreational, heritage and wildlife spaces, to create healthier and more resilient communities, particularly those with higher inequality or limited access to green space and contribute to ambitions for the Avon Corridor as a key green infrastructure resource.

Figure 16: Character Areas identified as part of the Placemaking Report[13]

2.8 Current arrangements

Numerical model simulations show that River Avon flooding occurs in two ways; by directly flooding properties adjacent to low points in the New Cut defences, and by indirectly flooding properties adjacent to the Floating Harbour after flood water has entered the harbour, filled it to capacity and then spilled into adjacent areas.

[13] Arup, "Placemaking Opportunities Report," 2020.

2.8.1 Bristol's Floating Harbour

Bristol's historic Floating Harbour was constructed to overcome the challenge of the second highest tidal range in the world. Opened in 1809, the river was diverted, and lock gates were installed so that the water level in the harbour remains constant, regardless of the level of the tide. In the 1870s, changes were made to Cumberland Basin and the harbour's water and silt level regulation.

Now, two pairs of BCC-owned lock gates west of Cumberland Basin and a pair of lock gates at Junction Lock maintain water levels at 6.2mOD and enable navigation during mid-tide. During high tide these navigation lock gates have no ability to hold back high river levels because they are mitred in the opposite direction, and so are opened to avoid damage due to reverse loading.

Fluvial flow enters the harbour from the River Avon via the Feeder Canal at Netham Lock diverted by Netham Dam, and also from the River Frome which passes through the centre of Bristol and enters from the north at Broad Quay and Castle Park. Flows discharge from the harbour via four culverts at Underfall Yard sluice, located close to Junction Lock. The schematic in Figure 17 shows the range of connected assets associated with controlling the Harbour, and their approximate locations, from which it can be seen that it is a relatively complex system.

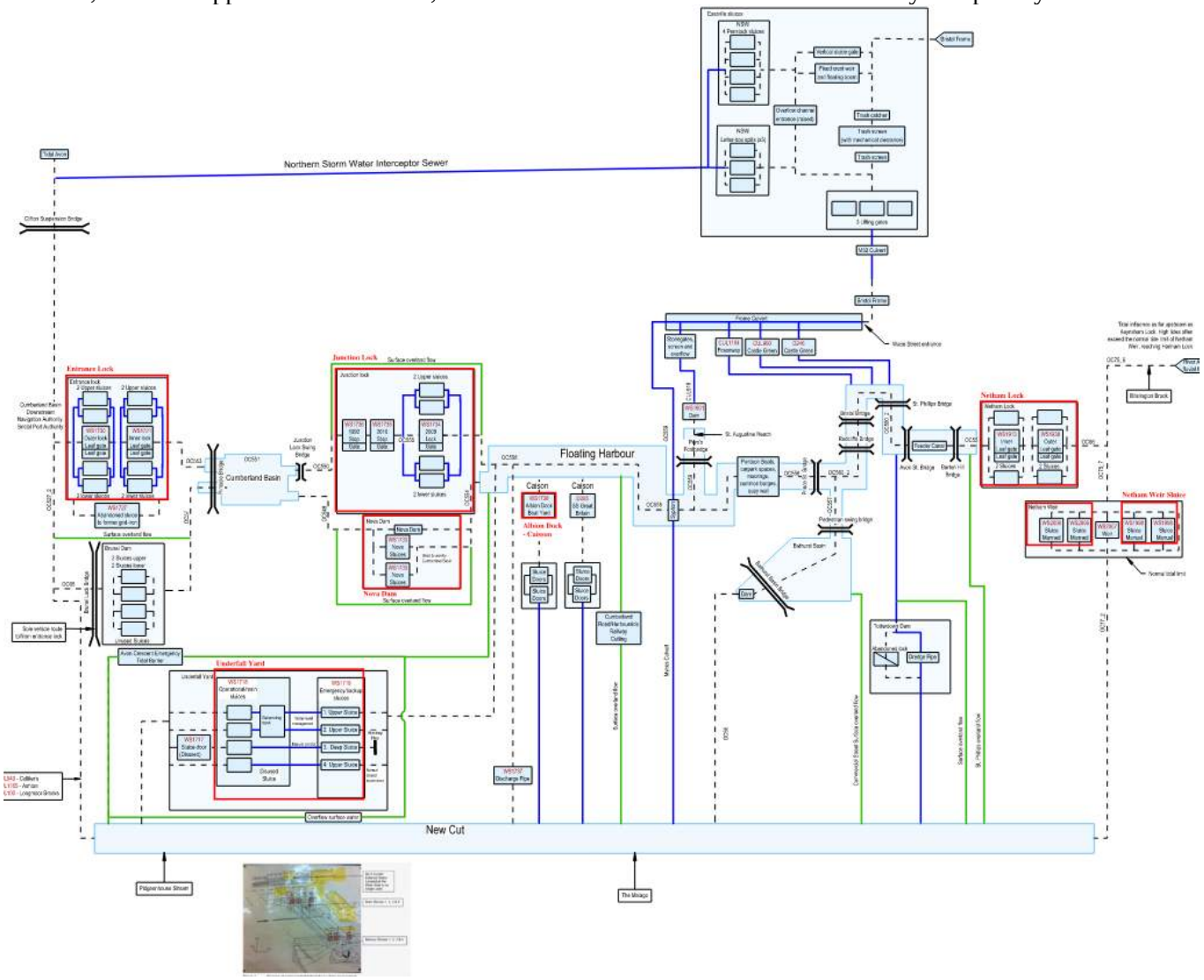


Figure 17: Asset schematic showing the numerous interconnected control structures around the Harbour

Figure 18: Netham Lock

At Junction Lock and Netham Lock the quayside levels adjacent to the stop gates are lower than the crest level of the gates, and if water levels exceed 8.2mOD, river water can overflow into the harbour. Other low points in the defences adjacent to the harbour also serve as entry points, such as Bathurst Basin Dam at 8.3mOD.

Figure 19: Water shown overtopping the Junction Lock stop gates into the Floating Harbour

2.8.2 Bristol's Floating Harbour operation

The harbour infrastructure and operating procedures aim to reduce the chance and consequences of overtopping into the Floating Harbour to reduce flood risk to large parts of the central Bristol. Two pairs of flood stop gates are deployed by BCC at Junction Lock (the downstream entry point to the harbour) to restrict water from flowing from the River Avon channel into the Cumberland Basin and then into the harbour. The stop gates are operated and maintained by BCC under a Memorandum of Agreement with the Environment Agency who pay for their operation. The Junction Lock stop gates are operated around 200 times every year but are otherwise left open. The manual lock gates at Netham (upstream entry point to the harbour) were refurbished in 2011, and restrict water entering at this entrance.

BCC works in partnership with the Environment Agency and Met Office to monitor river levels and rainfall and respond accordingly. In addition to the above, water levels in the Floating Harbour are typically lowered by 0.05m prior to a flood event to increase the storage capacity of the harbour. The maximum the harbour level can be reduced by is 0.5m.

The procedures to manage flood risk in central Bristol are reliant on effective and timely flood forecasting. The Environment Agency flood forecasting enables preparation, however, Bristol's 12m tidal range makes tidal forecasts challenging. Significant variations in predictions occurred during the lead up to peak tidal surge events in 1981, 1990, 2014 and 2020. Water levels are gauged by the Environment Agency upstream of Netham Weir and at Avonmouth, and by BCC at Bedminster Bridge.

The harbour's capacity is limited. The harbour's control infrastructure operation is extremely vulnerable to flooding and some key assets are approaching the end of their lives. As sea levels rise, the risk of operational failure increases.

An operational incident with the lock gates in 2006 almost led to the rapid draw down of harbour levels, risking the collapse of dockside walls. Despite a subsequent £11m refurbishment programme, operation remains dependent on human intervention and control infrastructure could become inoperable due to debris. Studies have highlighted the significant risk posed from boats, cars and other potential floating debris. Junction Lock hydraulic power units are resilient to flood levels up to 9.6mAOD.

Flooding at three main operational locations (Junction Lock, Netham Lock and Underfall Sluices) is predicted to be hazardous. Junction Lock is typically the most hazardous location, followed by Netham. At Junction Lock the hazard rating is 'Danger for most' during 1:75 events or above today, increasing to 1:20 by 2030. In this situation the operation of the stop gates at Junction Lock during a flood event is likely to be unfeasible.

The following considerations highlighted by the Central Area Flood Risk Assessment (CAFRA) Harbour Resilience Study (2013) are relevant when assessing future plausibility of maintaining gate deployment and harbour operations with minimal investment:

- No recent extreme tidal event has been recorded. Tidal stop gates have only been operated during events up to a 1 in 20 annual chance.
- BCC Harbour Master has noted the Netham Lock assets are manually operated and remote from the wider harbour operation.
- The Harbour's vulnerability increases significantly during more extreme events (especially as it relies on human intervention which may be hindered during a flood), and it will continue to increase in vulnerability as the impact of sea level rise is realised.

Figure 20: Clockwise from top left, Construction of Junction Lock, 1964[14], Brunel Harbour, 1929, Brunel's other bridge; Water rushes through the sluice gates of the dam built about 1890 to close off Brunel's lock, Cumberland Basin[15]

2.8.3 Containing river levels

Along the banks of the River Avon, low points include Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road. Raised defences in the city include the recently constructed MetroBus flood wall along a section of Cumberland Road and a combination of embankments and defacto defences at St. Philip's. The MetroBus flood wall (Figure 21) is constructed to 9.2mOD (present day 1 in 100 annual chance, 1% AEP). The St Philip's riverbank is narrow and the flood defences are lower at 8.8mOD and now in a variable condition, relying on some privately-owned walls and buildings with gaps as low as 8.4mOD. Private gabion wall flood defences reduce risk to the Paintworks development in Totterdown.

Figure 21: The MetroBus flood wall on Cumberland Road

2.8.4 Outside the city centre

Pill is located downstream of central Bristol, on the south bank of the River Avon. The frontage is defended to 9.3mOD by a sea wall constructed in the 1990s and a series of manually operated flood gates. Shirehampton is located opposite Pill, on the north bank of the River Avon, and includes a mixture of defences also built in the

[14] City Design Group, Bristol City Council, "Heritage Assessment – The River Avon", 2018
[15] Bristol City Docks, Cumberland Basin [Online], https://bristolcitydocks.co.uk/cumberland-basin

1990s to 9.35mOD and a set of manually operated raised flood gates. Several properties rely on standalone flood defences at Watch House Road. Maintenance is planned by the Environment Agency to address the durability of Pill's sheet piles following shore recession. The flood gates at Pill and Shirehampton are operated by the Environment Agency and rely on effective and timely flood forecasts. Nearby at Sea Mills, a number of low-lying properties have installed private property flood resilience measures.

Upstream of Bristol, several riverside properties between Hanham and Saltford had property flood resilience measures installed in 2016 to reduce the consequence of flooding, supported by the Environment Agency following repeated fluvial flooding. Environment Agency modelling predicted flooding to properties in proximity to Riverside Inn, Saltford (20% AEP), Swineford (1.33% AEP, with gardens 5% AEP), Broadmead Lane Industrial Estate (2% AEP) and Hanham/Riverside (50% AEP).

Throughout the area, low embankments and land drainage reduce the inundation of land downstream at Chapel Pill and upstream at Keynsham, for example at Broadmead Lane Industrial Estate where a flood plan seeks to reduce the risk posed from flood inundation.

2.8.5 Tributaries

Following catastrophic fluvial flooding in July 1968 where seven people died and more than 800 properties flooded, large tunnels (Airport Road Tunnel, Malago Interceptors and the Northern Storm Water Interceptor) have been built that significantly reduce the flood risk to large parts of the city by diverting flood water into the River Avon from tributaries such as the River Frome and Malago.

2.8.6 Management authorities

Flood risk in Bristol is currently jointly managed by BCC and the Environment Agency. BCC is responsible for operating the water level control infrastructure in the city centre, such as the tidal stop gates at Junction Lock and Netham, and the numerous sluice and culvert systems. BCC is also responsible for the upkeep of the retaining walls on the banks of the New Cut which act as a flood defence to the areas behind. The Environment Agency is responsible for providing flood forecasting and warnings to the area which are essential for the timely operation of the water level control infrastructure of the Harbour. In addition, the Environment Agency is responsible for the closure of manually operated flood gates at Pill and Shirehampton, as well as the deployment of temporary flood barriers in the city centre. The Environment Agency is also responsible for opening the Eastville Sluices, which relieves the Harbour and central Bristol area in times of high flow in the River Frome.

2.9 Main benefits

The Strategy will deliver a high standard of protection against flooding for Bristol and neighbouring communities, reducing the flood risk to properties, businesses, infrastructure and commerce to 2125 and beyond. Without the strategy, large sections of Bristol's city centre would be at potential risk of write-off of existing property or development blight. This will reduce the economic, social and environmental damage associated with flooding, as detailed in Section 3.5.6. The total economic benefit to the nation is over £980m when compared with the Do Nothing scenario, and over £820m when compared with Do Minimum.

In addition, as outlined in 3.5.7, potential local financial benefits are significant, by avoiding damage to properties and infrastructure, disruption to businesses and tourism, and unlocking sites for growth. These benefits are more than £7.7bn when compared with the Do Minimum scenario.

Whilst the key objective of this Strategy is to better protect people and property from flooding, it also brings opportunities to invest in public and wildlife spaces, improve walking and cycling links, enhance historic features and support regeneration, tackling the challenges of the climate crisis and building stronger communities (see Figure 22). The Strategy will also unlock developments in key areas around the city which are either currently at risk of flooding or will be in future. All of these would further contribute to the economic success and wellbeing of local people, businesses and visitors.

From an environmental perspective, the delivery of the strategy provides beneficial effects to people, health, material assets, heritage features and climatic factors, as well as opportunities for environmental enhancement and biodiversity net gain (e.g. native planting, urban greening etc.). These works are crucial to the preservation of key areas of Bristol that are fundamental to the character and make-up of the city and will better protect these areas from flood events arising from both tidal and fluvial flows.

Heading	Social	Economic	Environmental
Development: supporting economic vibrancy by providing the waterfront setting for existing and future major development sites.	New development establishes new communities and can create new destinations; increaseing activity and liveliness and natural surveillance of the public realm	Increased quality development promotes development and increases values and footfall for local businesses	Delivers a high quality, sustainable public realm that balances development, movement and nature
Landscape: creating a publicly accessible, linear greenspace; connecting healthy and well communities across the city.	As green infrastructure, landscape positively affects both mental and physical health	Landscape can provide a high quality, natural setting that increases land values and inward investment	Helps to mitigate climate change and air pollution through new tree planting
Movement: connecting people and jobs through enhanced walking and cycling links.	Active travel choices increase levels of activity and fitness, and the physical and mental health and wellbeing of the population	Providing better active transport choices helps to reduce motor vehicle usage and highway maintenance, with the associated cost benefits	Reduces motor vehicle use which will reducce air pollution and improve air quality
Heritage and Culture: protecting and conserving Bristol's harbour heritage. Supporting the visitor experience. Fostering opportunities to integrate public art.	Cultural heritage tells the story of places and communities by providing contextual identity	Stabilisation, repair and reuse of historic assets is a cost effective, sustainable approach	The repair, reuse and integration of historic assets is key to creating a quality environment, and helps to reduce the environmental impact of construction
Recreation: encouraging social and physical activity by designing in sociable places, fitness trails and resting spaces.	Fitness and play enhances and promotes healthy lifestyles and social activity	Encouraging a healthy population through recreation choices helps to reduce the costs of health care	Increased activity and liveliness in urban areas enhances a sense of ownership of the public realm
Nature: providing habitats and food for wildlife to enhance the biodiversity of the river corridor, and the movement of nature through the city.	Connection to nature has a positive affect on the mental and physical health of people	Nature based design approaches can reduce maintenance and operation costs	Reduces/ mitigates biodiversity lost through development

Figure 22: Key benefits identified as part of a wider placemaking strategy (Arup, 2020)

2.10 Main risks

A delivery risk register has been kept and updated throughout the development of the Strategy. Table 4 captures those considered the highest priority at this stage, and that could materially affect the delivery of the Strategy.

Key risk	Consequence	Response and action
Consultation procedural risk.	Delay or challenge to adoption and / or delivery of Strategy. Limited ability of stakeholders to influence strategy or predetermination.	Supportive engagement and awareness raising. Clarity of language and timing. Seek cross-party consensus and continue Stakeholder Working Group liaison.
Strategy endorsement by Environment Agency Regional Director or adoption by BCC Cabinet delayed.	Delay to adoption and / or delivery of Strategy.	Programme of briefings and reporting planned. Clear governance structure agreed.
Insufficient capital funding – either insufficient budget estimates or unaddressed funding gap.	Delay to flood strategy delivery. Lack of reasonable certainty of delivery sufficient for Environment Agency to consider strategy as part of planning and development consultee responses.	Environment Agency and BCC funding team support. OBCs to develop funding stream for works to be constructed in 2020s.
Landowner / occupier agreements protracted or delayed. Areas of land currently unregistered.	Programme delay and potential increase in costs for additional studies and mitigation measures.	Default strategy option minimises requirement for works on non-BCC land. Budget estimate includes compensation allowance. Embed agreements in policy.

Key risk	Consequence	Response and action
Challenge to scheme(s) consenting due to perception of third-party flood risk impact.	Programme delay and potential increase in costs for additional studies and mitigation measures.	Works to prevent adverse impacts have been developed in consultation with the Environment Agency. Affected communities to be engaged, identifying 'win-win' opportunities.
Flood strategy interface with rail assets at numerous locations.	Flooding of the railway will cause flooding to properties either side of the railway.	SOC recognises risk. Next stage to explore engagement with Network Rail.
The amended Strategy contains a number of direct impacts on heritage assets. Risk of further archaeological finds.	Potential significant increase in costs, delay or changes to proposed defences. Consent from Historic England / LPA.	Heritage baseline and assessment completed. Environmental documentation to be further updated in future stages. Engage with Historic England.
The design of measures to prevent adverse impacts has been undertaken to a different level of detail in comparison to the flood defence design	The impacts reported within the Environmental Report may change on closer inspection	Environmental documentation to be updated further at future stages, following greater definition of these defences

Table 4: Key risks, consequences and proposed responses

2.11 Constraints

There are a large number of constraints on the Strategy, including:

- The need to minimise disruption to adjacent businesses, transport networks and the community along the Avon, its tributaries and neighbouring communities.
- The need to maintain harbour structures, operation and navigation.
- The requirement not to increase flood risk (adverse impact) due to implementation of the Strategy through permanent or temporary works.
- The strategy needs a reasonable certainty of delivery, which will require agreement with the Environment Agency.
- Funding constraints, and those associated with other works taking place in the Strategy area, are discussed in other sections of this report.

2.12 Dependencies

2.12.1 Existing riparian assets

The Strategy is dependent on the New Cut retaining structures, banks of the River Avon, the harbour dam structures and the harbour water control assets at Underfall Yard. In addition, to ensure that navigation within the Floating Harbour continues it will be essential for the lock gates at Entrance Lock, Junction Lock and Netham to remain in operation throughout the duration of the Strategy – as demonstrated in Figure 17.

The external dependence on these existing assets and need for continued investment in the harbour outside of the scope of the Strategy is recognised by BCC. The cost of continuing to operate harbour assets is not fully known but BCC is committed to funding this. Following a recent comprehensive condition survey, an asset management strategy is scheduled to be completed and this will form the basis from which BCC will manage the existing assets. Regular monitoring and maintenance of the existing walls is also recommended to ensure they can retain the design flood events, as well as in the interests of public safety.

In 2018 BCC commenced preliminary inspections of existing infrastructure in and around the Harbour and New Cut. The condition of riparian retaining walls is poor in places and deteriorating. An asset condition survey carried out in 2019 highlighted that some were in 'serious' or 'critical' condition – most notably on Cumberland Road (see below) and also around the Paintworks, which are likely to require remediation prior to flood defences being constructed. Arup carried out a review of the harbour assets in serious or critical condition that are relevant to the Strategy[16]. Other riparian wall collapses include Clarence Road (2014) and Cumberland Road (1981).

2.12.2 Cumberland Road stabilisation works

BCC is currently delivering a £9m scheme to repair a 113m section of Cumberland Road riparian wall. The significant repairs address a collapse in January 2020 following long term increasing deformation due to ground failure. The proposed structure will support Cumberland Road, Bristol Harbour Railway and the Chocolate Path and comprises a contiguous bored pile wall and pile group tied together by a single concrete slab. The structure has been designed to allow the future raising of the Cumberland Road flood wall from the existing 9.2mOD to 10.5mOD to accommodate this Strategy's response to sea level rise.

Figure 23: Photo showing the collapse of the riparian wall on Cumberland Road in 2019

2.12.3 Partnership funding

The Strategy is dependent on the provision of partnership funding from FCERM-GIA sources. In order to progress an application for GiA it will also be necessary for the Strategy and then the OBC for the first phase works to be approved by the Large Projects Review Group (LPRG).

2.13 Interfaces with other projects

Emerging proposals and projects likely to influence the Strategy, and vice versa, are summarised below.

[16] Arup, "Bristol Flood Strategy; Updates to Proposed Defences".

2.13.1 Bristol Temple Quarter (BTQ)

BCC, working in partnership with WECA, Network Rail and Homes England are currently working on a long-term plan to guide how Temple Quarter and St Philip's Marsh develop in future. This includes a detailed plan for the transformation of Temple Meads station, as well as a long-term vision for the surrounding 70ha area.

The area was included in the Bristol Local Plan Review 2018[17] (Bristol City Council), which was consulted on in 2019. Following initial BTQ engagement in 2019, consultation on draft plans is anticipated. The development of the BTQ site will be limited if a city-wide flood risk management strategy is not approved and implemented, in particular a holistic approach to defending areas of Bristol.

Whilst this Strategy has identified a preferred way forward (see Section 3.7) which can be delivered using Environment Agency's Water Resources Act powers within the narrow river corridor, the emerging masterplan identified the ambition to set back defences to create a riverside greenway. As explored in the appended Placemaking Opportunities report (Appendix D), such an approach would unlock many wider benefits but is unable to be the default approach due to the delivery risk of land assembly. Defences proposed along Feeder Road also could be integrated into development frontages.

St Philip's Marsh redevelopment is likely to be a later phase and will require substantial enabling infrastructure. Precautionary planning assessments of residual flood risk, considering the risk of defence/gate failure, led to an emerging concept of a raised Resilient Access Network (RAN) constructed to provide access/egress above flood levels at all times with existing high ground combined with new elevated access roads. The RAN would facilitate movement around and away from St Philip's Marsh, as well as serving a number of wider objectives including utilities, green infrastructure and active travel. Options for delivery of the RAN are being explored.

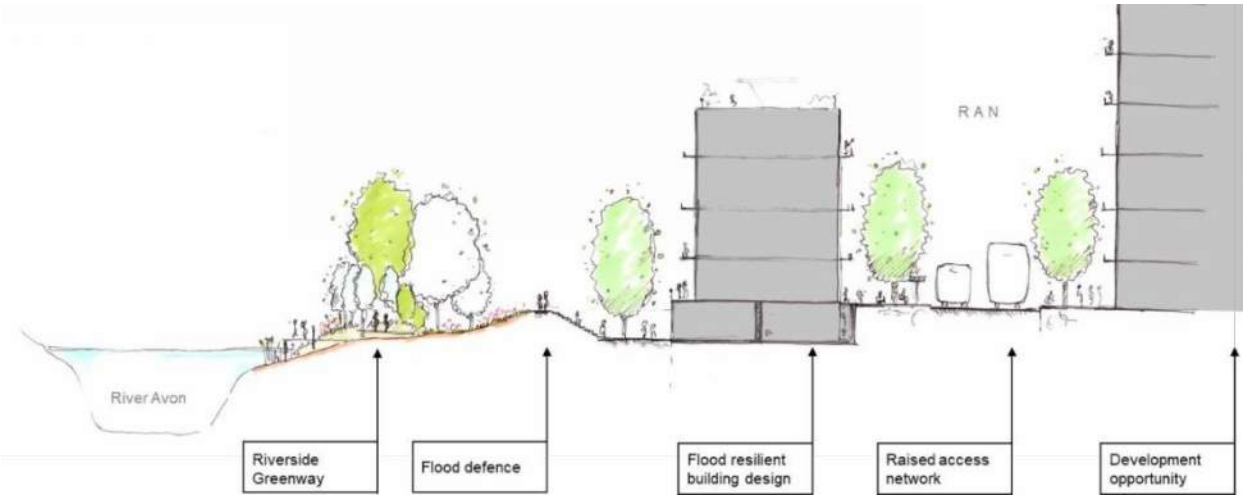


Figure 24: Example of how flood defences can be incorporated into BTQ development[18]

Delivery of the plan is constrained, both physically and by the needs of multiple landowners. Regeneration is therefore planned over several decades.

2.13.2 Western Harbour

The Western Harbour[19] was also included in the Bristol Local Plan Review 2018 as an area of growth and regeneration, consulted on in 2019. Proposals are at a very early scoping stages and a masterplan for the area has yet to be developed. Progress to date has included a Transport Feasibility Study and some early engagement on findings. Currently BCC is undertaking further engagement with stakeholders and communities to understand, capture and feed-in views for the area before commencing any further works.

[17] Bristol City Council, "Bristol Local Plan Review".
[18] Mott Macdonald, "Bristol Temple Quarter Masterplan Flood Risk Appraisal," 2020.
[19] Bristol City Council, "Western Harbour," [Online]. Available: https://www.bristol.gov.uk/planning-and-building-regulations/western-harbour.

There is significant scope for integrating the redevelopment of this area with proposed flood defences which can be explored at future stages. Delivery is constrained and regeneration is anticipated to be phased over the long term.

2.13.3 Pill

As works are likely to be required at Pill as part of the measures to prevent adverse impacts for this Strategy, this interface will be managed to ensure the schemes are compatible. The Environment Agency is investigating the case for works to sustain or improve the Standard of Protection within the Pill area, focusing on the Markham Brook tributary. Likely works include upgrades to a culvert, trash screen and pumping station on Markham Brook; and implementation of Natural Flood Management options upstream. Studies and engagement are ongoing.

Figure 25: Existing flood defences in operation at Pill

2.13.4 Lower River Frome

The River Frome discharges into the Floating Harbour, with the River Avon and harbour levels causing a backwater effect, increasing river levels and flood risk to properties in the lower River Frome area. The area is significantly constrained by flood risk, driven by limited pass-forward culvert capacity and considerations of necessarily precautionary Northern Storm Water Interceptor Tunnel failure scenarios.

BCC is currently engaging with stakeholders before preparing a development framework for the Frome Gateway, located adjacent to the lower River Frome and an area of growth and regeneration included in the Bristol Local Plan Review 2018 and consulted on in 2019. Proposals are at a very early scoping stage and a masterplan for the area has yet to be developed.
The Environment Agency is undertaking an SOC to make the case for asset repairs to sustain defences in the lower River Frome, including the NSWI Eastville sluices. In parallel, the Environment Agency is to complete a Bristol Frome Catchment Investment Strategy to identify the case for short-, medium- and long-term interventions to reduce flood risk and deliver wider benefits with partners BCC and South Gloucestershire Council. BCC and the Environment Agency will ensure that both schemes are compatible and benefits will not be ‘double-counted’.

2.13.5 Brislington Boat Screen

The Environment Agency are currently delivering £2m of works to the Boat Screen on the Brislington Brook. Refurbishments include access enhancements to address blockage risks of the trash screen and retaining wall repairs. The Strategy’s preferred option works to prevent adverse impacts include construction of a new wider inlet structure and screen.

2.13.6 Portway

BCC has been developing minor bank measures to reduce the onset of flooding to the Portway A4 in the Avon Gorge. There is a low-spot and the modest raised defences would reduce the onset of flooding to between 1 in 10 and 1 in 20 annual chance events in the present day. Construction is planned during the 2020-21 financial year. This is not expected to have a significant effect on the Strategy but will be modelled in future stages.

2.13.7 Sea Mills

Following March 2020 property flooding and ad-hoc engagement to inform the Flood Investigation Report, BCC plan to make improvements to flood risk modelling in the area of Sea Mills. The modelling will draw on both the upstream-focused CAFRA, and the modelling developed to inform the downstream Avonmouth Severnside tidal scheme.

2.13.8 Local cycling and walking infrastructure plan

The WECA Local Cycling and Walking Infrastructure Plan[20] includes proposed improvements to walking and cycling in the Strategy area. The Strategy may interface with emerging proposals for cycle path enhancements of St Philip's Marsh River Avon, Feeder Road and St Anne's, and Bedminster Bridges improvements.

2.13.9 North Keynsham

North Keynsham was identified as a strategic development location as part of Bath and North East Somerset Council work to develop their Local Plan, as part of the wider West of England Joint Spatial Plan (JSP). A 2017 initial strategic planning framework identified the potential (circa 1,400 new homes with supporting mixed land uses over the 150ha site)[21]. The site slopes to the River Avon and a riverside park was proposed for areas within the functional floodplain. Whilst the JSP was halted at the Examination stage and the Plan withdrawn in January 2020, technical assessments for the area have commenced to inform the future emerging Local Plan Review.

There is scope for integrating proposed works to prevent adverse impacts with development proposals which can be explored at future stages. Synergies will be pursued such as sharing of enhanced hydraulic modelling. Any regeneration is anticipated to be phased over several decades.

2.13.10 Review of Bristol Harbour

BCC is planning a wider Review around the whole of the Harbour leading to the development of a Harbour Strategy[22]. In 2020 the Council commenced a feasibility and case study project to provide market-rate comparators and key background information. The Review will commence engagement with all stakeholders and citizens as soon as possible in 2020.

[20] TravelWest, "Local Cycling and Walking Infrastructure Plan," [Online]. Available: https://travelwest.info/projects/local-cycling-and-walking-infrastructure-plan
[21] Bath & North East Somerset Council, "North Keynsham Strategic Planning Framework", [Online]. Available: https://www.bathnes.gov.uk/sites/default/files/sitedocuments/Planning-and-Building-Control/Planning-Policy/LP20162036/lp_201636_io_north_keynsham_strategic_planning_framework.pdf
[22] Bristol City Council, "Harbour Estate Review," [Online]. Available: https://democracy.bristol.gov.uk/ieDecisionDetails.aspx?AIId=18194.

2.13.11 Bedminster Green

Central Bedminster is proposed as an area of growth and regeneration, focused on a number of vacant or underused sites clustered around the River Malago. The Bedminster Green Framework[23] was approved by BCC in March 2019 and sets out guidelines for planning applications on five plots, includes the aim to *"Open up and enhance the Malago where feasible to create an asset for amenity, sustainable drainage, urban cooling, wellbeing and habitats. Flood attenuation and management potential should be increased, to benefit the neighbourhood."* BCC is working in partnership with developers, and, supported by the Environment Agency, is developing proposals for river restoration. The Strategy has assessed the impact of the preferred option in the area and from 2065 measures are proposed to temporarily store water during times of extreme river flows in the Marksbury Road open space to mitigate low levels of adverse impact downstream.

[23] Bristol City Council, "Bedminster Green Framework," [Online]. Available: https://democracy.bristol.gov.uk/ieDecisionDetails.aspx?AIId=15476.

Economic Case

Is there a case for change?

Figure 26: Flooding along Sea Mills Lane during 11th March 2020 tidal surge

3 Economic Case

3.1 Introduction

Throughout this section, 'options' should be considered as preferred strategic approaches or ways forward, as opposed to finalised engineering designs.

3.2 Appraisal boundaries

The appraisal period adopted is 100 years, based on the expected design life of any interventions. The geographic boundaries of the appraisal are set by the range of hydraulic influence of interventions at the Floating Harbour – i.e. analysis has taken account of any detriment to property caused by those works & account of any detriment mitigation, both in terms of costs and benefits.

3.3 Critical success factors

The critical success factors identified below were used to differentiate between options and formed the basis of the options assessment. The most important critical success factor is the reduction of flood risk to existing communities; however, the wider objectives and potential benefits of the scheme are acknowledged.

Critical Success Factor	Measurement Criteria
To support the safe living, working and travelling in and around central Bristol by ensuring flood threat is reduced and that measures address residual risks.	• No. of people better protected against flooding over the whole life of the Strategy • No. of residential and commercial properties better protected from flooding over the whole life of the Strategy • No. of key infrastructure assets better protected from flooding • Adverse impact to other areas managed to within agreed acceptable limits
To ensure the strategy is technically feasible and has a reasonable certainty of delivery. Associated risks can be reasonably managed to ensure timely delivery. Optimise benefits and outcomes to demonstrate value for money.	• Delivery of Strategy to provide agreed scale of flood risk management • A costed option which maximises the benefit to cost ratio • Planning permission granted • Required partnership funding contributions identified and secured to achieve final PF score >100% • Key stakeholders are supportive of proposals. Communities are aware and understand project benefits and timescale • Health, safety and wellbeing of all involved
To facilitate the sustainable growth of Bristol and the West of England by supporting opportunities for employment and residential land, and infrastructure.	• New employment opportunities created • Sustainable development in areas benefitting from Strategy
To maintain natural, historic, visual and built environments within the waterfront corridor and where possible	• No net loss of key habitat and enhancement where possible • Compliance with regulations

Critical Success Factor	Measurement Criteria
deliver enhanced recreational, heritage and wildlife spaces	• Protection of cultural heritage assets • Placemaking opportunities realised
To ensure navigation of river and marine activities continue.	• Number of vessel journeys affected • Continuation of existing activities

Table 5: Critical success factors

3.4 Long list options

A long list of options was considered for managing the flood risk for Bristol City Centre. The long list development and appraisal was undertaken in the 2017 Study.

In developing this Strategy, further development of the longlist has not been undertaken but below is a summary of the long list options considered and their appraisal to the shortlist. More details on the long list is provided in section 3.3 of the 2017 Study. Figure 27 outlines the process. The long list was reviewed and considered appropriate. Whilst the 2017 Study has not been assured by Environment Agency's Large Project Review Group, a working session on 27th April 2017 discussed the emerging case for change and the long list was reviewed and considered appropriate.

Although additional work was carried out as part of this Strategy that has changed the costs of the raised defences options, it was noted in the sensitivity testing of the 2017 Study that with an increase in raised defences cost *"the relative economic merits of each option would be largely unchanged".* Similarly, *"should the barrier cost reduce by 50% the barrier options still remain significantly higher than the cost of the preferred option".*

A wide range of techniques or "measures" were considered as part of the longlist. These include:

- Source techniques to slow the flow upstream to reduce the peak flow or techniques to keep out the tide
- Pathway techniques to increase the river capacity to contain flood water within the river channel and convey flow downstream or storing flood water.
- Techniques to increase the resilience of receptors such as people, property and the environment to withstand the impact of flooding better.

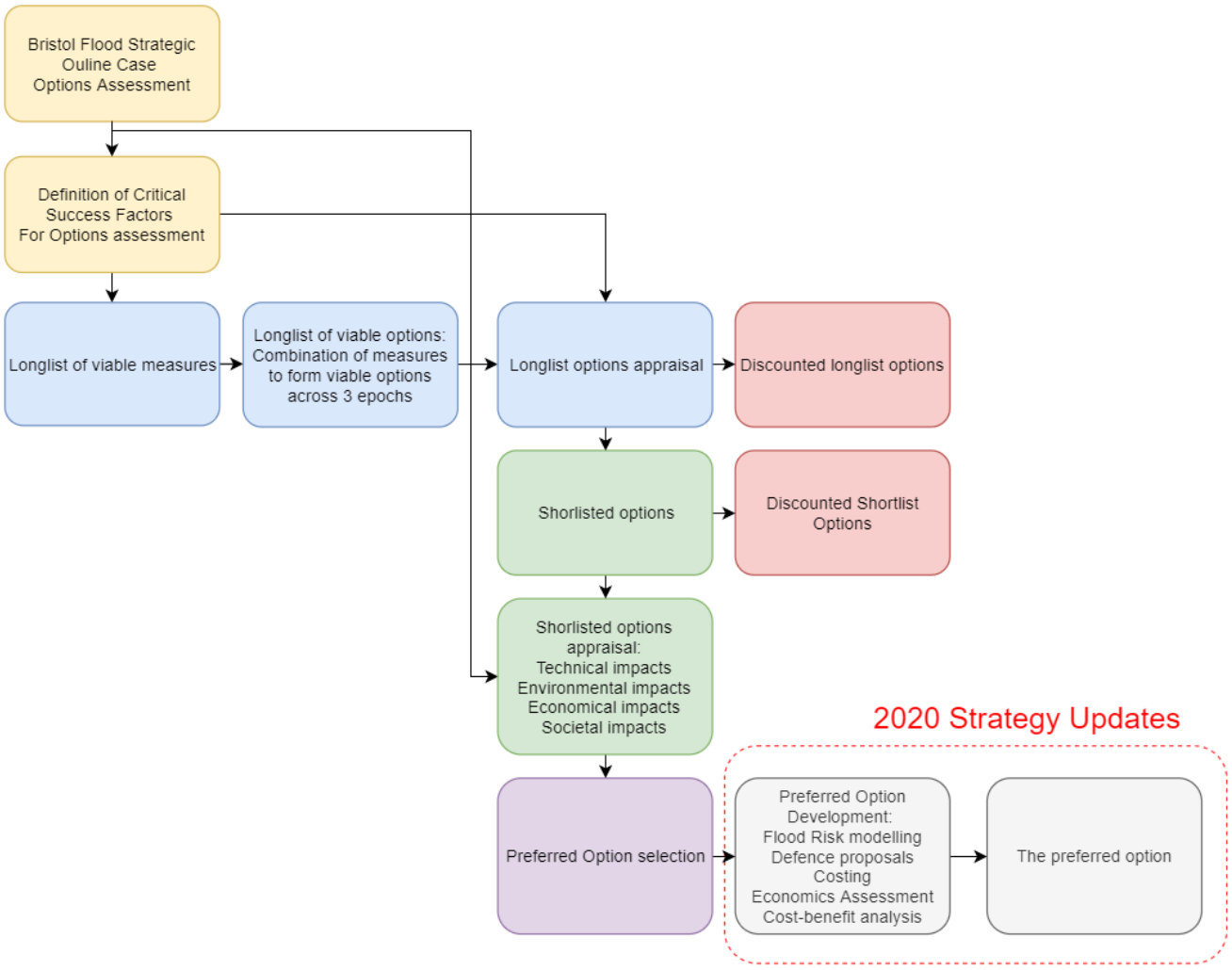


Figure 27: Representation of the optioneering process across the 2017 and into 2020

A number of measures were discounted as they were not considered technically feasible. Table 6 summarises the techniques taken forward to form long list strategic options.

Measure	Description	Commentary	Outcome
Do Nothing	A cessation of all maintenance and operations, with gates assumed to be in open position	No benefits delivered	Not considered an acceptable or viable approach in Bristol. Included as a baseline against which strategic options could be compared.
Do Minimum	Maintain the 'status quo' i.e. continued maintenance of all existing defences and the existing Floating Harbour water level control structures, but no new defences and no raising of defences.	No additional benefits delivered	Not considered an acceptable or viable approach in Bristol. Included as a baseline.
'Low' defences	Constructing new defences, to a chosen standard of protection for 2030, as an interim measure	Flood risk management up to 2030 required funds only to provide part of the defence.	Considered viable to take to the shortlist in combination with other measures.

Measure	Description	Commentary	Outcome
'High' defences	Constructing defences to a chosen standard of protection for 2115. Implemented by constructing a new defence or raising a low defence.	Flood risk management up to 2115. Construction of new defences require funds in Epoch 1. Raising of existing defences is considered and may achieve cost savings.	Considered viable to take to the shortlist in combination with other measures.
Wide tidal barrier	Construction and operation of a tidal barrier across a 'wide' section of the River Avon downstream of Bristol at Pill and Shirehampton, approximately 500m upstream of the M5 road bridge	Flood risk management against tidal flooding. High cost and high-risk option with negative environmental impacts. Potential secondary uses include generation of tidal energy and provision of transport links.	Considered viable to take to the shortlist in combination with other measures.
Narrow tidal barrier	Construction and operation of a tidal barrier across a 'narrow' section of the River Avon downstream of Bristol at Ham Green / Nibley Road, approximately 1500m upstream of the wide barrier option location.	Flood risk management against tidal flooding. Traps fluvial flows when barrier shut and raised defences would be required in conjunction with barrier. Relatively higher cost and higher risk option than other measures considered. Will have considerable negative environmental impacts.	Considered viable to take to the shortlist in combination with other measures.
Local scale measures	Property resilience measures (such as flood plans, flood doors and flood resilient buildings) and temporary defences	Increases receptor resilience can increase the capacity of people, property and the environment to withstand the impacts of flooding and to rapidly recover after a flood. Only suitable for shallower depths of flooding. Manual deployment can be required presenting residual risk.	Considered viable to take to the shortlist for suitable individual properties only. The scale, depth and speed of predicted flooding is too great to rely on these on their own. Need to be considered with other measures.

Table 6: Summary of long list measures

Discounted flood defence techniques include:

- Source techniques to **slow the flow upstream** to reduce the peak flow (such as flood storage, working with nature or land management) were discounted on technical grounds due to the impractically large scale of required upstream works for the 2,200km^2 upstream catchment and the fact that this approach would not reduce tidal flooding from the estuary. This concurs with catchment flood management planning and similar options appraisals for upstream schemes such as the recent FCERM options appraisal for the Bath flood scheme itself with a slightly smaller upstream catchment.

- Source techniques which **keep out tidal surges** include tidal barrages (permanently damming the river and controlling water levels upstream, such as the Cardiff Bay barrage) and tidal barriers (closes at times when flood tides are forecast, such as the Thames Barrier in London). A barrage would be significantly more costly than a tidal barrier and would have significant negative impacts on habitats, landscape, fish passage and navigation of the river. A barrage would increase upstream flood risk as the River Avon does not have enough space to store river flows. Potential for wider benefits to be incorporated into a barrier solution (e.g.

synergies with a new transport link crossing the River Avon or tidal energy generation) were considered but this failed to improve the economic case. A tidal barrier was included in the long list.

- Pathway techniques to **increase the river flow conveyance capacity** (such as dredging or constructing a flood relief channel or tunnel) could potentially reduce fluvial flooding however these has been discounted as they would increase tidal flood risk by allowing more water to flow up the river from the estuary and space is constrained. **Storing the flood water** in the Floating Harbour as it overtops low spots along the River Avon, with levels lowered at times when flooding is forecast. However there is not enough storage space in the harbour and it would be overwhelmed during a severe flood.

Strategic long-list options were then formed by assigning measures to each time epoch (noting that three epochs were used during the 2017 Study, and now only two are proposed). For instance, an option could comprise local scale measures followed by low and then high defences. Each long-listed option was developed sufficiently in terms of concept and spatial influence and potential form to ensure an adequate understanding of potential option impacts was achieved in order to carry out a robust appraisal with sound decision making. A long list of thirty-nine reasonable strategic options were assessed for the short list.

3.5 Shortlist options

The appraisal of the long list of options to shortlist of options included a multi-criteria assessment whereby each long list option was scored against the Strategy objectives (as described in section 2.7) in equal measure. The total score of each of the thirty-nine long listed options across the Strategy objectives was used to select the short list of Options. From this assessment, the options in Table 7 were discounted for the outlined reasons.

Long List Option	Description	Commentary	Reasons for discounting
Wide barrier	As per Table 6	• Highest capital costs estimated between £550-600million • Estimated less than 20% GiA contributions from partnership funding calculation • Potential other uses may include generation of tidal energy or provision of transport links. • Project risks may include challenges to obtain environmental consents and Transport and Works orders for example • High environmental impacts anticipated: Barrier location adjacent to key environmental designations. • Other potential impacts include: Landscape and visual, ecological (Terrestrial, Estuarine and River), heritage and archaeological, geomorphology, water quality and traffic and transport	• High cost • High delivery risk • No significant improvement to the economic case or the funding gap from additional uses • Significant environmental impacts across multiple receptors • The benefits of the wide barrier option can largely be achieved by combining alternative measures with lesser negative impacts such as the narrow barrier or high defence measures.

Long List Option	Description	Commentary	Reasons for discounting
PLP / Temporary barriers	As per Table 6	Not considered a viable long-term solution due to operational risks	Discounted as a standalone option but may be considered as an interim option (short term) with other measures.

Table 7: Options discounted from assessment

Based on the scoring and a moderation/rationalisation process, a short list of seven strategic options covering both precautionary and adaptive approaches were selected. The options scoring the highest from the multi-criteria assessment were adaptive approaches providing the flexibility to build defences to the level required for each epoch and thus requiring funds in phases. Precautionary approaches where defences are built to provide flood protection to 2115 in Epoch 1 scored lower but were still considered viable short list options. The resulting short list was comprised of seven strategic options (denoted A-G), in addition to the Do Nothing and Do Minimum scenarios. Table 8 is a summary of the shortlisted options as presented in Table 8 from the 2017 Study.

Option	Option Title	Epoch 1 (2015-2030)	Epoch 2 (2030-2065)	Epoch 3 (2065-2115)
	Do Nothing	No maintenance, no new defences	No maintenance, no new defences	No maintenance, no new defences
	Do Minimum	Do Minimum approach, existing defences maintained but no new defences, no defence raising	Do Minimum approach, existing defences maintained but no new defences, no defence raising	Do Minimum approach, existing defences maintained but no new defences, no defence raising
A	PLP* – Low Defences – High Defences	Property level measures and temporary barriers used to mitigate flood risk	Linear flood walls built to protect Bristol to a chosen standard in 2030.	Additional linear flood walls built to protect Bristol to a chosen standard until 2115, with existing walls being raised or replaced as necessary
B	PLP – High Defences – High Defences	Property level measures and temporary barriers used to mitigate flood risk	Linear flood walls built to protect Bristol to a chosen standard to 2115.	Walls maintained, standard falls over time to chosen standard in 2115
C	PLP – Narrow Barrier – Narrow Barrier	Property level measures and temporary barriers used to mitigate flood risk	'Narrow' tidal flood barrier built to protect Bristol to a chosen standard or higher, for the next 100 years	Barrier maintained, standard falls over time to chosen standard or higher
D	Low Defences – Low Defences – High Defences	Linear flood walls built to protect Bristol to a chosen for 2030.	Walls maintained, standard falls over time.	Additional linear flood walls built to protect Bristol to a chosen standard until 2115, with existing walls being raised or replaced as necessary
E	Low Defences – Narrow Barrier– Narrow Barrier	Linear flood walls built to protect Bristol to a chosen for 2030.	'Narrow' tidal flood barrier built to protect Bristol to a chosen standard or higher, for the next 100 years	Barrier maintained, standard falls over time to chosen standard or higher

Option	Option Title	Epoch 1 (2015-2030)	Epoch 2 (2030-2065)	Epoch 3 (2065-2115)
F	High Defences-High - High	Linear flood walls built to protect Bristol to a chosen for 2115.	Walls maintained	Walls maintained, standard falls over time to 2115
G	Do Min – Do Min – High Defences	Do Minimum approach, existing defences maintained but no new defences	Do Minimum approach, existing defences maintained but no new defences	Linear flood walls built to protect Bristol to a chosen standard until 2115

Table 8: Shortlist of strategic options taken forward

3.5.1 Short list options assessment

The short list options appraisal consisted of a qualitative assessment of each of the short listed measures against the Strategy objectives and critical success factors. Each shortlisted measure was appraised on their technical viability, environmental impact and other impacts such as cost, buildability and socio-economic impact. In addition to the technical and environmental assessment undertaken in the 2017 Study, a red, amber, green (RAG) colour scheme has been used to indicate the viability of each measure. Refer to the short list qualitative appraisal table in Appendix E for a more detailed assessment of the shortlisted options.

A key change from the 2017 Study to that currently proposed is moving from three epochs to two. The proposed phases 1 (construction in 2020s) and 2 (2030s), were combined due to the minimal difference in water levels between 2025 and 2035, and because the vast majority of proposed defences were found to require construction phase 1. This is explained in more detail in a report[24] produced to support modelling for the Bristol Temple Quarter masterplan

By developing strategic options in accordance with these time epochs it has allowed an adaptive approach to be developed that keeps pace with climate change and potential changes in predicted sea level rise. In addition, the approach has in-built flexibility to address future uncertainty to ensure that the timing of future works is appropriate.

3.5.2 Selecting the preferred option

An economic appraisal including assessment of costs and damages and benefits was carried out on each of the seven shortlisted options.

The strategic options (Options C and E) with barrier measures, could not be economically justified (costing significantly more to construct) and the appraisal of non-economic benefits did not yield significant reasons to select them over other options. Extensive raised defences would still need to be built in the city centre to contain river flows trapped at times the barrier was closed, despite testing barrier locations as far downstream as possible. Therefore, these options were discarded.

The options comprising of low defence, high defence and PLP measures (Options A, B, D and F) show economic justification for the increased investment to implement defences in epoch 1 or 2 rather than deferring to epoch 3, without any significant adverse issues so the Do minimum and High defence option (Option G) was discarded.

The economic case for the low defence options (Options A and D) and the high defences options (Options B and F) were very similar. However, considering the Strategy objectives in terms of earlier investment in defences to better support wider growth and development opportunities, options involving PLP measures (Options A and B) were discarded.

The Low defence option supporting an adaptive approach (Option D) was selected as the preferred option over the high defence precautionary option (Option F) for the following reasons:

[24] Arup, “Hydraulic modelling to support Bristol Temple Quarter project”, 2019

- Lower cost, and significant part of cost deferred until 2065
- High defence construction deferred until 2065, deferring adverse visual impacts.
  A more adaptable approach, with Low Defences constructed in epochs 1 and ability to review the requirements of the High Defences in epoch 2 with a more accurate view of sea level rise projections.

3.5.3 Development of the preferred option

The preferred option developed in the 2017 Study has been further developed as part of this Strategy. Although based on an adaptive approach, additional complexity is introduced in the form of different climate change allowances (and hence a range of defence heights), works to address adverse impacts and placemaking opportunities, which formed a new set of options.

A key uncertainty from the 2017 Study was fluvial flood risk which needed to be addressed. As part of the 2020 Strategy, further flood modelling was undertaken to assess the flood risk from fluvial effects as well as update the modelling to assess tidal flood risk for an appraisal period of 2025 to 2125. Two epochs have been considered in the flood modelling to determine the required standard of protection in 2065 and 2125[25]. A significant change as a result of this modelling was that higher defences are needed earlier, and that this requires significant foundations which increase the Phase 1 epoch costs whilst reducing the Phase 2 epoch costs.

Flood modelling to assess the adverse impact to properties and proposed works to prevent adverse impacts was carried out on the developed preferred option, to manage any increase in flood risk to properties caused by the proposals.[26]

3.5.4 Approach to costing

To develop the costing of the preferred option, a bottom-up approach has been used. The updated modelling work defines the levels, height and lengths of the flood defences and works to prevent adverse impacts. A high-level assessment of the 2017 Study defences was carried out, and changes proposed to defences to cater for the increased wall heights whilst ensuring technically feasibility.[27] Updated unit rates for the defences were used to calculate the cash cost of the individual flood defences and works to prevent adverse impacts.

As well as requiring an assessment of costs required for different standards of protection (return periods) and across epochs (i.e. construction to 2065 and 2125) costs were also developed for different climate change allowances (FCERM and NPPF).

The adverse impact assessment focussed on the Flood Risk Assessment (FRA) requirements, therefore to develop and test options to prevent adverse impacts, the NPPF climate change allowances were used.

For flood defences that are designed to provide a given SoP to receptors behind the defence, allowance has been made for freeboard to manage the uncertainty in modelled water levels. However, where the flood defence is used purely to prevent detriment, a freeboard allowance is not required. Therefore, for costing of the works to prevent adverse impacts, flood defences have been based on the higher of the FCERM water levels with freeboard and NPPF water levels without freeboard.

To enable the cost-benefit assessment for the strategy, the cost of the scheme has been derived for a number of scenarios with different Standards of Protection (SoP) incorporating both adaptive and precautionary approaches as shown in Table 9. Allowances have been made for other costs such as services and diversions and other costs and fees to develop the scheme to construction.

A 60% optimism bias was then applied in line with FCERM-AG recommendations for Strategic level studies. For Reach 2 (Cumberland Road) where detailed design tendered cost information was used, the optimism bias was

[25] Arup, “Bristol Flood Risk Management Strategy, Overview of flood modelling”, 2020
[26] Arup, “Bristol FRM Strategy, Detriment Mitigation Testing”, 2020
[27] Arup, “Bristol Flood Strategy; Updates to Proposed Defences”, 2020

reduced to 46% using a risk-based approach in line with the FCERM Appraisal Guidance[28]. Refer to Appendix C for definition of the reaches.

Scenario	Phase 1 (2020s)	Phase 2 (2065)
1B	Construct to FCERM 2065 50yr SoP by 2025	No work, i.e. do not raise
2B	Construct to FCERM 2065 75yr SoP by 2025	No work, i.e. do not raise
3B	Construct to FCERM 2065 100yr SoP by 2025	No work, i.e. do not raise
4B	Construct to FCERM 2065 200yr SoP by 2025	No work, i.e. do not raise
5C	Construct to FCERM 2065 50yr SoP by 2025.	Raise in 2065 to FCERM 2125 50yr SoP
6C	Construct to FCERM 2065 75yr SoP by 2025.	Raise in 2065 to FCERM 2125 75yr SoP
7C	Construct to FCERM 2065 100yr SoP by 2025.	Raise in 2065 to FCERM 2125 100yr SoP
8C	Construct to FCERM 2065 200yr SoP by 2025.	Raise in 2065 to FCERM 2125 200yr SoP
9A	Construct to 2065 NPPF 100/200yr SoP without freeboard by 2025 everywhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP without freeboard everywhere
9B	Construct to 2065 NPPF 100/200yr SoP with freeboard by 2025 everywhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP with freeboard everywhere
10A	Construct to 2065 NPPF 100/200yr SoP without freeboard by 2025 for reaches 1 and 7 only. Construct to FCERM 2065 75yr SoP by 2025 elsewhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP without freeboard for Reaches 1 and 7 only. Raise in 2065 to FCERM 2125 75yr SoP elsewhere
10B	Construct to 2065 NPPF 100/200yr SoP without freeboard by 2025 for reaches 1 and 7 only. Construct to FCERM 2065 100yr SoP by 2025 elsewhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP without freeboard for Reaches 1 and 7 only. Raise in 2065 to FCERM 2125 100yr SoP elsewhere
10C	Construct to 2065 NPPF 100/200yr SoP without freeboard by 2025 for reaches 1 and 7 only. Construct to FCERM 2065 200yr SoP by 2025 elsewhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP without freeboard for Reaches 1 and 7 only. Raise in 2065 to FCERM 2125 200yr SoP elsewhere
11A	Construct to 2065 NPPF 100/200yr SoP with freeboard by 2025 for reaches 1 and 7 only. Construct to FCERM 2065 75yr SoP by 2025 elsewhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP with freeboard for Reaches 1 and 7 only. Raise in 2065 to FCERM 2125 75yr SoP elsewhere
11B	Construct to 2065 NPPF 100/200yr SoP with freeboard by 2025 for reaches 1 and 7 only. Construct to FCERM 2065 100yr SoP by 2025 elsewhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP with freeboard for Reaches 1 and 7 only. Raise in 2065 to FCERM 2125 100yr SoP elsewhere
11C	Construct to 2065 NPPF 100/200yr SoP with freeboard by 2025 for reaches 1 and 7 only. Construct to FCERM 2065 200yr SoP by 2025 elsewhere.	Raise in 2065 to 2125 NPPF 100/200yr SoP with freeboard for Reaches 1 and 7 only. Raise in 2065 to FCERM 2125 200yr SoP elsewhere
12A	Precautionary approach; construct to NPPF 2125 without freeboard for Reaches 1 and 7 and FCERM 2125 75yr SoP everywhere else by 2025	No work
12B	Precautionary approach; construct to NPPF 2125 without freeboard for Reaches 1 and 7 and FCERM 2125 100yr SoP everywhere else by 2025	No work
12C	Precautionary approach; construct to NPPF 2125 without freeboard for Reaches 1 and 7 and FCERM 2125 200yr SoP everywhere else by 2025	No work
13A	Precautionary approach; construct to NPPF 2125 with freeboard for Reaches 1 and 7 and FCERM 2125 75yr SoP everywhere else by 2025	No work
13B	Precautionary approach; construct to NPPF 2125 with freeboard for Reaches 1 and 7 and FCERM 2125 100yr SoP everywhere else by 2026	No work
13C	Precautionary approach; construct to NPPF 2125 with freeboard for Reaches 1 and 7 and FCERM 2125 200yr SoP everywhere else by 2027	No work
14A	Precautionary approach; construct to NPPF 2125 with freeboard everywhere else by 2025	No work
14B	Precautionary approach; construct to NPPF 2125 without freeboard everywhere else by 2025	No work

[28] Environment Agency, "Flood and Coastal Erosion Risk Management Appraisal Guidance," 2010.

Scenario	Phase 1 (2020s)	Phase 2 (2065)
15C	Construct to 2065 NPPF 100/200yr SoP without freeboard by 2025 for reaches 1 and 7 only. Construct to FCERM 2065 200yr SoP by 2025 elsewhere.	Raise in 2065 to FCERM 2125 200yr SoP everywhere

Table 9: Summary of costing scenarios

The input assumptions and cost output for each of these scenarios are listed in Appendix C of the Updates to Proposed Defences Report.[29]

Table 10 below shows how little costs vary between comparable standards of protection: this is driven by relatively small differences in defence heights or lengths between options, and the need to build in adaptability to future defence raising through building larger foundations in 2025.

Option	Description	Standard of Protection	2025 CAPEX (£m)
5C	Construct in 2025 to 2065 FCERM standard. Uplift in 2065 to 2125 FCERM Standard	1 in 50 year	211.5
6C		1 in 75 year	213.7
7C		1 in 100 year	215.3
8C		1 in 200 year	223.3
9A (local choice)	Construct to 2065 NPPF 100/200yr SoP without freeboard. Uplift in 2065 to 2125 NPPF Standard without freeboard.	Greater of 1 in 100year fluvial / 1 in 200yr tidal	215.9

Table 10: Comparison of Capex costs for different FCERM adaptive approach schemes

Public realm enhancement costing

The costs quoted above are based on public realm works commensurate with a consentable FCERM scheme in line with the Grant in Aid rules. A higher level of public realm intervention was assumed for the Knuckle/Entrance Lock area due to the landscape sensitivity and significance. The *consentable FCERM scheme* public realm rate of £400/m^2 was based on an allowance for alterations to general layout, use of basic materials, limited interventions. Costs include allowance for these minor enhancements/interventions along a nominal 3m wide corridor.

The costing of the defences also considered allowance for a higher level of public realm enhancement, recognising Bristol's ambitions for greater placemaking. The *high public realm* rate of £560/m^2 was defined as alterations to general layout, creation of extent of public realm, seating, lighting, tree planting and Sustainable Drainage Systems (SuDS). The difference is shown below.

Option	Public realm option	2025 CAPEX (£m)
Local Choice	Consentable FCERM scheme	215.9
Local Choice	High public realm	235.7

Table 11: Comparison of costs of the Local Choice scheme with different public realm interventions (placemaking)

3.5.5 Economic appraisal

This assessment looks at the economic case for the scheme; the basis for selection of the preferred scheme using the FCERM Decision Rule; and the case for "local choice" of an alternate scheme that facilitates Bristol's greater ambitions.

The assessment has undertaken analysis of Grant in Aid eligible benefits, which are attributable to the reduction of flood risk, and reflect economic impacts on the nation. These will form the basis for the assessment of the quantum

[29] Arup, "Bristol Flood Strategy; Updates to Proposed Defences".

of DEFRA Grant in Aid that may be available to the scheme, as calculated using the Partnership Funding Calculator (PFC).

The assessment has also analysed local benefits, reflecting the financial impacts on the City of Bristol of addressing flood risk. This may form the basis of bids to alternate sources of funding, further supporting the development of the scheme.

Further details of the assessment are available in the Economic Appraisal Technical Report[30], Appendix H.

3.5.6 Damages assessment

Economic losses from the predicted flood risk have been estimated using the Flood Hazard Research Centre's Multi Coloured Manual (MCM)[31] methodology. The avoidance of damage from flooding to residential and non-residential property fabric and contents is the principal benefit for the purposes of the economic assessment (so called 'direct' damages).

In addition, the below 'indirect' damages have also been estimated:

- Emergency Services
- Utilities damages
- Indirect commercial impacts due to flooding to businesses
- Costs of evacuation
- Vehicle damages
- Risks to Life
- Mental health
- Rail disruption
- Traffic disruption
- Intangible Benefits

The assessment to date has not taken account of the carbon losses associated with flood damages, and given the high flood damages assessed, these could be considerable.

The shortlisted options for the economic assessment were as follows:

- Do Nothing
- Do Minimum (described in 2.2)
- Construction of flood defences

Do Nothing

Under the Do Nothing scenario, the flood gate protective structures at Netham Lock and Junction Lock are no longer powered, supported or maintained. In the absence of proactive management of the gates, they would not be closed on time; the lock gates managed by the Harbour Master are not constructed to hold back flooding. The lock gates / flood gates are modelled as being static and open.

The Avon through Bristol is not subject to active maintenance and increases to roughness or bed levels have not been assumed in the Do Nothing scenario.

Do Minimum

The Do Minimum option assumes that the lock gate and flood gate protective structures at Netham Lock and Junction Lock are maintained and refurbished over the appraisal period so that, if operated successfully, they provide a significant reduction in flood risk in flood events.

The default modelled scenario in the Do Minimum is therefore that the locks are managed in a timely fashion prior to a flood event, and are managed proactively during the event so that the levels of fluvial events entering the Floating Harbour do not cause flooding by being prevented from leaving the docks.

[30] Arup, "Economic Appraisal Technical Report," 2020
[31] Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, 2013 Flood Hazard Research Centre

However, the locks have had near misses during past flood events, where due to equipment failure, electrical failures, and traffic disruption impacting on staff availability, flood control systems were difficult to operate. Although this has not caused a significant issue yet, it will become more of an issue as flood risk are increasing and events are becoming more common. Notably, the need for proactive management during a flood event does not allow deployment of the gates to be limited to a single operation in advance of a flood.

In flood events greater than a present day 12 year fluvial event, or a 20 year tidal event, flood flows bypassing the lock gates via the quays on either side are fast and deep, achieving hazard ratings of "*dangerous to most*" or above; and it may reasonably be considered that there is a very significant chance of failure to close the gates. In the largest tidal and fluvial events, the tide has been witnessed carrying significant volumes of debris, (including vehicles), which may impair the function of the gates.

The Do Minimum economic modelling reflects this by reverting to the outputs of the Do Nothing modelling in these events.

Construction of flood defences

As explained in section 3.5.3, the assessment of flood defences is based on an adaptive approach to raised defences. A range of standards of protection have been considered in the assessment, to facilitate assessment of the Decision Rule and to allow identification of a range of options for the development of the "Local Choice" preferred option, particularly with a view to management of climate change.

Development of flood defence options

As a starting point, scenarios have been built around the concept of constructing a scheme in 2025 on a precautionary basis, the standard of which will decline against time to meet a given standard in 2065, at which point the defence would be raised again to a higher level, the standard of which will decline against time to meet the given standard in 2125 at the end of scheme life.

For example: To provide a 75-year standard of protection (SoP) on this basis (and considering only the tidal component for now), the scheme would need to be built to the equivalent of a ~250year scheme in 2025. Over time, this SoP would decline, reaching a 75-year SoP in 2065. At this point in time, the scheme would be raised to what would be, in 2065, the equivalent of 1540 year standard of protection. However, over time, this too would decline to a 75-year standard of protection by the end of scheme life.

This example is a good illustration of why this adaptive approach is necessary. Had the scheme not been raised in 2065, the 75-year scheme would have continued to decline such that by 2125, it would have had an SoP equivalent to 3.5years – the property it protected would be at risk of being written off.

On the other hand, to construct on a fully precautionary basis to the 2125 75year standard of protection would have meant that, when constructed, the scheme would have had an SoP equivalent to the 2025 5250-year event. This would be potentially excessive, and it is noted that the defence heights in some locations are significant: their visual and amenity impact is reduced by deferring construction to the 2125 standard. The difference between 2065 and 2125 defence heights is typically 0.50 - 0.60m.

The options considered are for a 75-year, 100-year and 200-year SoP, corresponding to 6C, 7C and 8C in Table 9.

Overlaps

The analysis into impacts on the local economy covers the same area geographically as the flood damage assessment. Where proposals are being assessed for their potential to unlock future development, care has been taken to manage overlaps.

Understanding of development proposals in Bristol has been informed by BCC's available "Economic Development Needs Assessment" dataset (EDNA), which presents disparate development initiatives, generally in a near time frame of 0-10 years, and by various masterplan documents relating to Bristol's more strategic and longer-term Growth and Regeneration initiatives.

For properties overlapped by proposed developments set out in the EDNA dataset, it is assumed that damages are only accrued for a 5-year period. This is because the development of those sites will lead to replacement of the

properties on those sites with NPPF compliant construction. After that time, only 10% of damages are accrued, reflecting the assumed likelihood that some developments do not proceed.

For properties overlapped by Bristol's more extensive masterplan ambitions, the timelines of those masterplans have been taken into account. Damages can still be accrued up till the expected delivery timelines of those developments. Properties can still be written off if at high risk in the Do Minimum and Do-Nothing scenarios.

Benefits

Capped PVD damages are shown in Table 12 below. It is

	Do nothing	Do minimum	75yr SoP	100yr SoP	200yr SoP
Damages (£m)	1046	886	66	65	52
Benefits (£m)	0	160	980	981	994
Intangible benefits (£m)	0	5	28	28	29

Table 12: Summary of economic benefits of options

Costs

Net present value costs of each option have been calculated as described in 3.5.4, and are summarised in Table 13.

	Do nothing	Do minimum	75yr SoP	100yr SoP	200yr SoP
Capital works, 2020s (£m)	0	14	213.7	215.3	223.3
Capital works, 2060s (£m)	0	0	7.9	7.9	7.9
Whole life maintenance (£m)	0	5	24.1	25.2	25.5
Whole Life Costs (£m)	0	19	245.7	248.5	256.7

Table 13: Summary of present value costs of options including optimism bias

Benefit cost ratios

Having calculated the benefits and costs of each option, a benefit cost ratio, and the incremental benefit cost ratio (IBCR) can be calculated as per Table 14.

	Do nothing	Do minimum	75yr SoP	100yr SoP	200yr SoP
Damages (£m)	1046	886	66	65	52
Benefits (£m)	0	160	980	981	994
Whole Life Costs (£m)	0	19	246	249	257
Benefit Cost Ratio	-	8.4	4.0	3.9	3.9
ICBR to next option	9	3.6	0.3	1.6	-

Table 14: Benefit cost ratios for each option

Application of the Decision Rule

From the Do Minimum, an IBCR>1 is required to progress to a subsequent option. The analysis indicates an IBCR >3.

From the 75yr SoP, an IBCR>3 is required to progress to consideration of the next option, and this is not achieved, but only just. The cost differential between the 75yr and 100yr scheme is very small, but so is the benefit differential. This makes the 75yr SoP option the "preferred scheme on economic grounds" and this is the basis on which Grant in Aid should be calculated.

Therefore, the scheme that the calculation of Grant in Aid should be based on is a 75 year scheme, constructed to the 2065 75yr standard in 2025 and uplifted to the 2125 75yr standard in 2065. This is scenario 6C from Table 9.

The Grant in Aid associated with this option is **£68.5m**, based on the payments for outcomes shown in Table 15. The calculated value of Grant in Aid is low compared to the overall value of damages, and the proportion of damages associated with residential properties in the floodplain. From review of the mechanisms behind this, it appears that Bristol is particularly subject to high levels of "capping" and write-off. Capping is a process to avoid more benefit or damage being claimed for a property than the property is actually worth, and property is written off if its flood frequency exceeds 33% Annual Exceedance Probability. This process not only limits the value of benefits claimed, it also changes the percentage make up of "People related" benefits that would pay out at a more generous rate. Bristol is subject to particularly high rates of capping and write-off because it is at risk from both tidal and fluvial flooding, and tidal flooding is particularly sensitive to the effects of climate change.

Outcome Measure	Damage type	Qualifying benefits (£m)	%age of benefits	Payment rate (p/£)	Eligible Grant in Aid
OM1a	Overall damages	844	86.1%	6	50.6
OM1b	People related	118	12%	20	23.6
	Deprivation				
OM2	20% most deprived	0.25	0.0%	45	0.1
	21% to 40% most deprived	7.5	0.8%	30	2.3
	60% least deprived	10.7	1.1%	20	2.1
TOTAL		**980.4**	**Pv. max eligible GiA**		**78.7**

Table 15: Payment for outcomes from the Partnership Funding Calculator

Local Choice

Bristol City Council's ambitions for Western Harbour, Bristol Temple Quarter and St. Philip's Marsh merit the consideration of an NPPF compatible standard of protection. Such a scheme would be constructed to the greater of the 100-year fluvial, or 200-year tidal SoP, with greater allowances for climate change.

The defences however would not need to be constructed with freeboard, because uncertainty in flood risk can be managed by development behind the defences through their own application of freeboard in their floor levels. Comparison of such a scheme suggests that both phases of such a scheme would have defence heights higher than the Grant in Aid eligible scheme.

The cost analysis suggests that in Net present terms, the NPPF scheme would be slightly more expensive than the Grant eligible scheme, at £225m NPV capital works (compared to £222m for the grant eligible scheme).

3.5.7 Local benefits

The Environment Agency / Defra Flood and Coastal Erosion Risk Management Grant in Aid (GiA) fund is determined based on the national economic benefits flood damages avoided. The effects on the local economy, of interest to BCC will not necessarily be taken into account in such an assessment, and these effects are set out in this

section. The unit of impact is a monetary measure of the value added by businesses to the local economy termed Gross Value Added, GVA.

The benefits assessed include:

- The "first order" losses associated with direct flood impacts on commercial property
- GVA losses saved through reduced flood risk to existing businesses
- GVA earned through jobs created by the unlocking of development on the floodplain
- GVA earned through jobs created by construction of the strategy and the unlocked development.
- GVA losses saved through reduced flood risk to the tourist industry
- Potential health and amenity benefits generated through enabling the creation of a sustainable transport network next to the River Avon.

The calculations and methodology are set out in more detail in Appendix H, and the results are summarised in Table 16.

	Benefit compared with Do Nothing	**Benefit compared with Do Minimum**
Commercial property damage and infrastructure disruption avoided	£405m	£281m
Disruption to businesses avoided	£250m	£250m
Growth enabled at unlocked sites (EDNA sites)	£5,635m	£5,635m
Growth enabled at unlocked sites (Growth and Regeneration sites)	£1,513m	£1,513m
Jobs created through construction	£25m	£25m
Disruption to the tourism sector avoided	£263m	£21m
Benefit of enabling green transport infrastructure	£18m	£18m
TOTAL	**£8,109m**	**£7,743m**

Table 16: Potential local benefits of the Strategy

Clearly the bulk of these benefits are associated with the growth enabled at unlocked sites. It is important to recognise that identification of the potential local benefit of the scheme is not the same as claiming all these benefits toward a funding application. Flood risk is not the only infrastructure issue to be resolved to enable the unlocked sites or the greenway, and the benefits identified above would need to be apportioned across a number of infrastructure investments. However, without resolving flood risk, it is true to say that these developments will only proceed with significant delay or cost.

Further work would be necessary to resolve this analysis in greater detail, and in particular this should focus on assessing the potential benefits associated with unlocking the Growth and Regeneration sites and resolving the potential overlapping claims to infrastructure funding associated with these sites.

3.6 Non-financial benefits appraisal

The objectives for the Strategy are as set out in section 2.7. The economic and flood-risk benefits have been described in previous sections, with the remaining objectives focussing on technical robustness, continuation of navigation, environmental sustainability and the facilitation of growth.

All of the options were considered acceptable from a navigation perspective. Tidal barrier options presented a significant potential impact, but technical studies undertaken showed that feasible designs could be implemented without significantly constraining navigation. Environmental assessments are described in 3.8.

3.6.1 Development opportunities

A key objective of the options was to facilitate the sustainable growth of Bristol and the West of England by supporting opportunities for employment and residential land, and infrastructure. In particular, this includes areas of growth and regeneration at Bristol Temple Quarter and Western Harbour (see 2.13).

All the raised defence options support this objective as they will provide a higher standard of protection against flooding, reducing potential development constraints. The Strategy area will generally become a more viable location for development.

An adaptive approach will also allow for integration between development opportunity and the Strategy. Lower defences mean greater flexibility to adapt to changing development needs, whereas if high defences were constructed straight away, it could be constraining.

The Local Choice option described above allows a NPPF-compatible standard of protection to be in place for development and therefore is likely to be more attractive to potential developers.

3.7 Preferred option

As described in the preceding sections, the preferred way forward is to construct raised defences in the Strategy area, from Shirehampton and Pill, through central Bristol and upstream to Keynsham and Swineford. These will be constructed in two phases. The extent of the defences is shown in the drawings in Appendix C.

The preferred option specifies the construction of defences to the NPPF SoP for 2065 in the 2020s. Further work has been undertaken to split this phase into ‘build stages’, as the construction of each phase is likely to take several years and be delivered in discrete packages. The works in each stage have been determined on the basis of need, potential impacts on development, harbour operation and adverse impact. These phases are indicative as they are subject to further modelling, investigations and detailed design.

Build stage 1 - estimated 2025-2027 at a capex cost of £89m:
- Entrance and Netham Lock flood gates
- Works in Shirehampton, Pill and Sea Mills;
- Works upstream of St Anne’s;
- Brislington Brook
- St Anne’s
- Bower Ashton

Build stage 2 - estimated 2027-2028 at a capex cost of £127m:
- Remainder of city centre defences

In the 2060s, defences will be raised as necessary to the higher of the 200-year FCERM or NPFF SoP for 2125. This will also require the construction of some additional defences in new areas:
- Pill
- Totterdown (near the Paintworks)
- The Malago

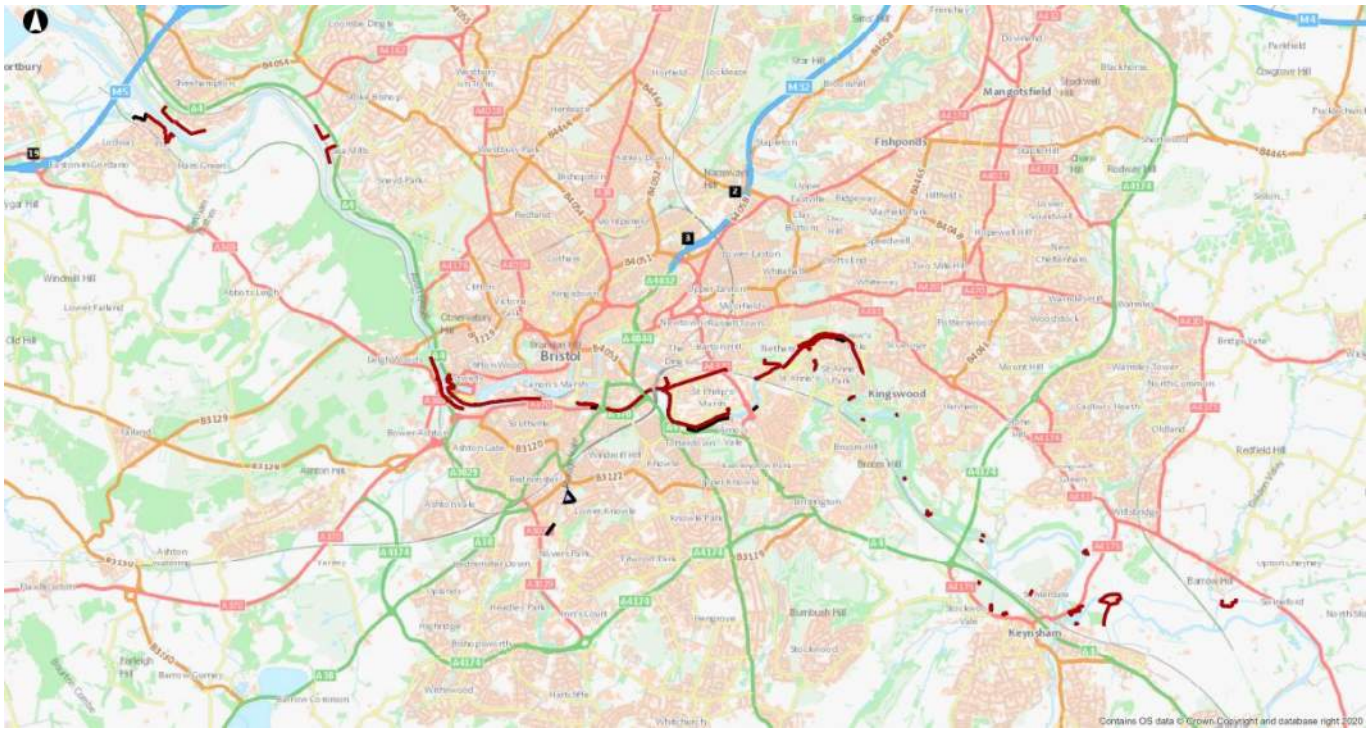


Figure 28 Extent of Proposed Measures

The costs and benefits of Stages 1 and 2 have been approximated as shown in Table 17.

Build Stage	Components	Benefits (£m)	Capital works (£m)	Estimated Grant in Aid funding (£m)	Funding required (£m)
1	Entrance & Netham Lock flood gates. Detriment mitigation works	228	89	14	75 (84% of build)
2	The remainder of Phase 1.	753	127	55.3	72 (57% of build)

Table 17: Costs, benefits and GiA estimate for build stage 1 and 2

3.7.1 Engineering design

At this preliminary stage, engineering designs for budget cost estimating have been developed as well as to highlight potential risks and opportunities. No engineering design has been completed on works to integrate the defences into the public realm for wider benefits. Surveys, engagement and design is planned during subsequent stages.

The Updates to Proposed Defences report (Appendix G) gives details of each defence solution, summarised in Table 18. Works to prevent adverse impact are required upstream of St Anne's, as far upstream as Swineford. Due to reduced certainty in the hydraulic model and topographic information in this area, the engineering designs are less advanced here than for the rest of the Strategy.

Defence section	Structure type	Defence level, mAOD (2065)	Defence level, mAOD (2125)	Length of section (m)

Entrance Lock / Western Harbour *	Concrete and sheet pile flood walls, flood / lock gate replacement, replacement of Brunel Dam, ramps, road raising	10.05	10.80	1350
Cumberland Road	Piled flood wall, flood gate	10.10	10.80	866
Commercial Road and Bathurst Dam	Concrete flood wall, dam raising, ramps	10.15	10.75	310
Clarence Road	Concrete flood wall	10.25	10.7	570
Cattle Market Road	Piled flood wall	10.20	10.7	250
St Philip's Marsh *	Concrete wall on angled minipiles, flood gate, ramps, embankment	10.25	10.75	1488
Netham *	Concrete flood wall, wall raising, embankment, flood gate.	10.40	10.95	715
Bower Ashton	Embankment	10.05	10.8	940
Totterdown (South)	Raising of existing wall	-	10.75	440
Feeder Road *	Contiguous piled flood wall	8.75	9.05	880
St Anne's (North)	Sheet piled flood wall	11.00	11.4	1414
St Anne's (South)	Sheet piled flood wall	11.05	11.45	1010
Shirehampton	Embankment, wall raising	9.90	10.50	850
Pill	Wall raising, embankment	9.85	10.45	1075
Sea Mills	Embankment	10.00	10.60	350
Chapel Way (Brislington Brook)	Embankment	14.30	14.30	210
Measures upstream of A4174	Embankment / walls. Property Level Protection may be suitable	Various	Various	Various

Table 18: Summary of defence section types and levels for the chosen SoP

In general, defences constructed during the 2025-2065 period would be parapets, typically 0.5-1.2m above general ground level, allowing people seated beside immediately adjacent footways or paths unobstructed views of the horizon. High defences proposed through Epoch 2 (2065-2125) would be designed to allow for the impact of sea level rises and could require defences to be increased in height a further 0.5m-0.6m. Precautionary allowances of climate change associated with the NPPF would require approximately a further 0.3m to be added to defence levels.

The Strategy has been developed with flexibility in mind. For instance, BCC can work with potential developers to incorporate the appropriate standard of protection into new developments. This may involve bringing forward the delivery of flood defences in areas of developments or changing designs to fit with those constructed by developers. It is also possible that some areas could be delayed to avoid defences being constructed by BCC only to

be replaced by developers. However, this would require agreement to ensure that there is not an unacceptable risk to properties should development be delayed. The reaches indicated with a * symbol in Table 18 are thought to be most likely to involve overlap with developers.

3.7.2 Placemaking

Flood defences can be integrated into wider multi-functional public realm infrastructure. In the absence of designs, a placemaking opportunities study has explored aspirational opportunities that align with the Strategy's strategic objectives[32]. The study focused on four character areas, shown in Figure 16. The study investigated the site characteristics of each area and how flood defences could benefit them in terms of development, landscape, nature, movement, recreation, heritage and culture. Aspirational visualisations for the character areas are shown in Appendix D.

Figure 16 shows the network of green spaces around the River Avon and the opportunity to create a green corridor for health, wellbeing and wildlife benefits. The corridor has many strategic transport nodes with the potential to establish strong connections along the E-W river corridor with N-S links into the city.

Figure 29: Network of green spaces identified around the River Avon to create a green corridor

The additional cost of placemaking measures has been estimated as £20-£28m depending on how much is implemented (see Table 11). It will be BCC's choice as to whether to proceed with this additional work, but should be noted that additional placemaking may be necessary to ensure delivery of the scheme, as well as helping to realise the benefits already discussed.

The scheme costs given in Table 13 include the minimum required for a consentable scheme. As further placemaking elements are not Grant in Aid eligible they have not been included in the PFC.

3.7.3 Strategy Carbon Impact

BCC, supported by the Environment Agency, will work to develop solutions that efficiently minimise whole life carbon impacts. Following the carbon management hierarchy, the Strategy can make a lasting contribution through options that avoid, reduce and replace carbon. Do-something options avoid the carbon impact of the emergency response and recovery prompted by widespread flood events in the absence of investment.

Development of the Strategy preferred strategic approach will include lower carbon options for detailed appraisal unless they are likely to be very significantly more expensive at achieving other scheme objectives than alternatives, or poor at achieving other scheme objectives.

In advance of submission of this SOC to the Environment Agency for assurance, the Carbon Modelling Tool will be completed to provide a baseline.

3.8 Environmental compliance

A number of environmental reports have been produced to demonstrate the environmental compliance of the preferred option for the Strategy, as outlined below.

[32] Arup, "Placemaking Opportunities Report", 2020

3.8.1 Strategic Environmental Assessment (SEA)

A SEA has been undertaken as an integral part of the option appraisal process and this assessed the likely significant effects of the emerging strategy in terms of key environmental issues. The SEA comprehensively assessed the proposed flood management approach and evaluated the environmental impacts of different options.

The SEA and SEA Addendum found that although all of the options have a potential for significant adverse impacts during both construction and operation, it also identified benefits from the implementation of the flood defences, including the beneficial effects on people, health, material assets, heritage features and climatic factors. These works are crucial to the preservation of key areas of Bristol that are fundamental to the character and make-up of the city and will protect these areas from flood events arising from both tidal and fluvial flows. The SEA and SEA Addendum have identified a number of negative effects, some of which are likely to be significant. Further work, alongside existing studies including the Placemaking Opportunities report should be undertaken to further develop the design to minimise the impact on the environment and those effects reported.

The SEA found likely significant effects to the following environmental topics for the preferred option of the Strategy:

- Biodiversity, flora and fauna, including intertidal habitat (negative – note these are associated with construction and there are opportunities for enhancement throughout the Strategy);
- Cultural Heritage (negative & positive)
- Population, human health and material assets (positive)

Similarly, minor effects were identified for:

- Landscape;
- Soil/Water; and
- Climatic Factors.

A number of mitigation measures have been outlined in the SEA to avoid potential adverse effects and has identified the need for further work to ensure environmental compliance as the Strategy develops. Opportunities for potential enhancements through the Strategy which would benefit wildlife include built-in bird, bat and insect boxes or bricks integrated within the proposed defences, kingfisher perches, areas of wildflower meadow for pollinating insects, green walls, the planting of berry-bearing trees and shrubs and nectar-rich flowering plants

Habitat Regulations Assessment (HRA) and a Statement to Inform an Appropriate Assessment (SIAA) (Stage 2) have been undertaken by Arup as part of the SEA Addendum to reflect the changes to the amended Strategy and with regards to recent case law. The SIAA provides an assessment of the potential for effects on European Sites from the implementation of the proposed works.

The SIAA undertaken has reported that the potential pathway for effects at construction includes habitat loss and degradation, habitat severance, disturbance, and species mortality / injury. There are no predicted potential operational effects from the amended Strategy.

As detailed design progresses, and consultation with statutory bodies continues, it is anticipated that baseline survey and supporting information will provide further assessment on the potential for adverse effects to arise. Without further baseline and supporting survey information at this stage, and without avoidance and/or mitigation measures, it is reasonable to conclude there could be adverse effects on the integrity of the European Sites.

To allow the competent authority to conclude no adverse effect, further survey and mitigation measures are required. Winter bird surveys and habitat assessments are required, in part, to understand the impact of the proposed works on the Severn Estuary SPA, Ramsar and SAC, and the Avon Gorge Woodlands SAC. Any habitat management or reinstatement, with respect to impacts on the European Sites, may require monitoring and further management. Refer to the SIAA for full details.

3.8.2 Water Framework Directive (WFD)

An updated Preliminary WFD Assessment has been produced by Arup as part of the SEA Addendum which includes an assessment of all water bodies that could be affected by the implementation of the amended Strategy, including their current water quality status.

The updated Preliminary WFD Assessment concluded that the piling involved for any defences has the potential to intercept groundwater levels, however there are currently no groundwater Source Protection Zones (SPZ) in the scheme area, and no groundwater abstractions close to the River Avon that would be likely to be affected. As such, impact to groundwater is scoped out of this WFD assessment. This statement should be reassessed in the future as new groundwater abstraction licences could be granted near the River Avon, within the Triassic Groundwater body that could potentially be impacted by piling. The Preliminary WFD Assessment found that there is potential for impacts on the Bristol Avon water body, as well as the Floating Harbour as the construction of defences in currently undefended areas has the potential to impact the ecological status of the water bodies, as this will likely involve a reduction of aquatic habitat areas, as well as potentially having a negative effect on hydromorphology. The Preliminary WFD Assessment therefore recommends that a full WFD Assessment will be required to evaluate the total combined length and percentage of the water bodies affected to assess the overall significance of the impacts. As whilst an individual scheme may have an insignificant impact on WFD quality elements within a reach, the combined effect of several small-scale schemes within a water body may cause deterioration. It is intended that a full WFD Assessment will be carried out and submitted as part of a future Environmental Impact Assessment (EIA).

3.8.3 Environmental Impact Assessment (EIA) pre-scoping

An EIA pre-scoping report has been produced by AECOM to provide a framework for the future EIA process. The pre-scoping report identified the key environmental issues to be:

- Terrestrial Ecology;
- Estuarine Ecology;
- Landscape;
- Archaeology and Heritage;
- Land Quality and Land use; and
- Traffic and Transport.

The pre scoping report made a number of recommendations including the next steps for the EIA process.

3.8.4 Environmental enhancements and biodiversity net gain

As the Strategy progresses through the OBC, detailed design and delivery stages, opportunities for environmental enhancement will be sought. In particular this includes an ambition for biodiversity net gain. Net gain is an approach to development that aims to leave the natural environment in a measurably better state than beforehand. As the Strategy is refined further, and detailed defence design takes place, every opportunity should be taken to minimise net loss of intertidal saltmarsh and mudflats. Ultimately, measures will be devised and presented as part of the detail to support a planning application that must commit to no net loss approach of intertidal habitat Biodiversity Net Gain.

The loss of coastal habitats may require creation/enhancement of intertidal habitats of a greater area than the area lost. Considering the constraints of the river corridor and urban environment, this will require creative, innovative solutions. This could include intertidal habitat built into ‘grey’ infrastructure (such as rock pools), additional planting and habitats incorporated into defences to create wildlife corridors.

At OBC stage, a net gain options appraisal is to be carried out to consider how this has been achieved in similar locations, to ensure that this thinking is captured sufficiently early in the Strategy’s development.

Figure 30: Porter Brook pocket park, Sheffield, winner of the Living Waterways contribution to the built environment category 2016[33]

3.9 Residual risk

Residual risk for the Strategy has two main elements: risks associated with the failure of the defences and risks associated with events occurring which exceed the design parameters of the defences. It should also be noted that some flooding will still occur in the design event once the Strategy has been implemented, however as demonstrated in Figure 31 and Figure 32, the reduction in flooded area for the city of Bristol is significant for each SoP.

[33] The Landscape Institute, "National Living Waterways Awards winners announced", [Online] Available: https://www.landscapeinstitute.org/news/national-living-waterways-awards-winners-announced/

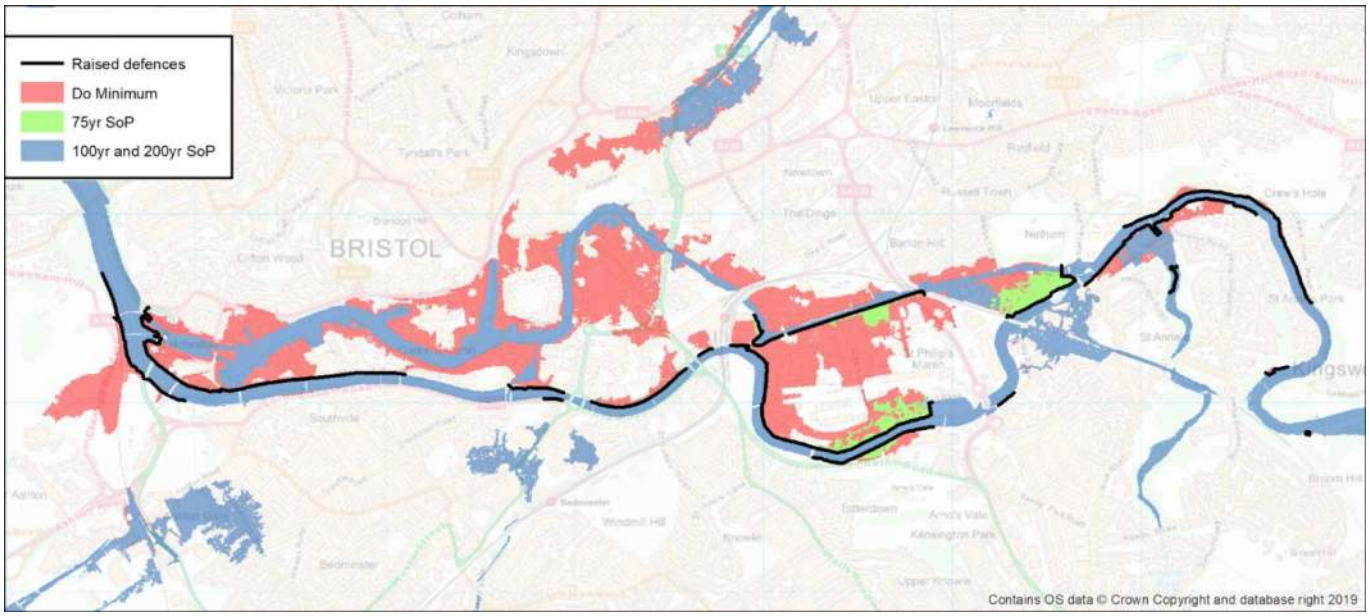


Figure 31: Flood extents of raised defences options vs Do Minimum for 2125 fluvial 100yr event.

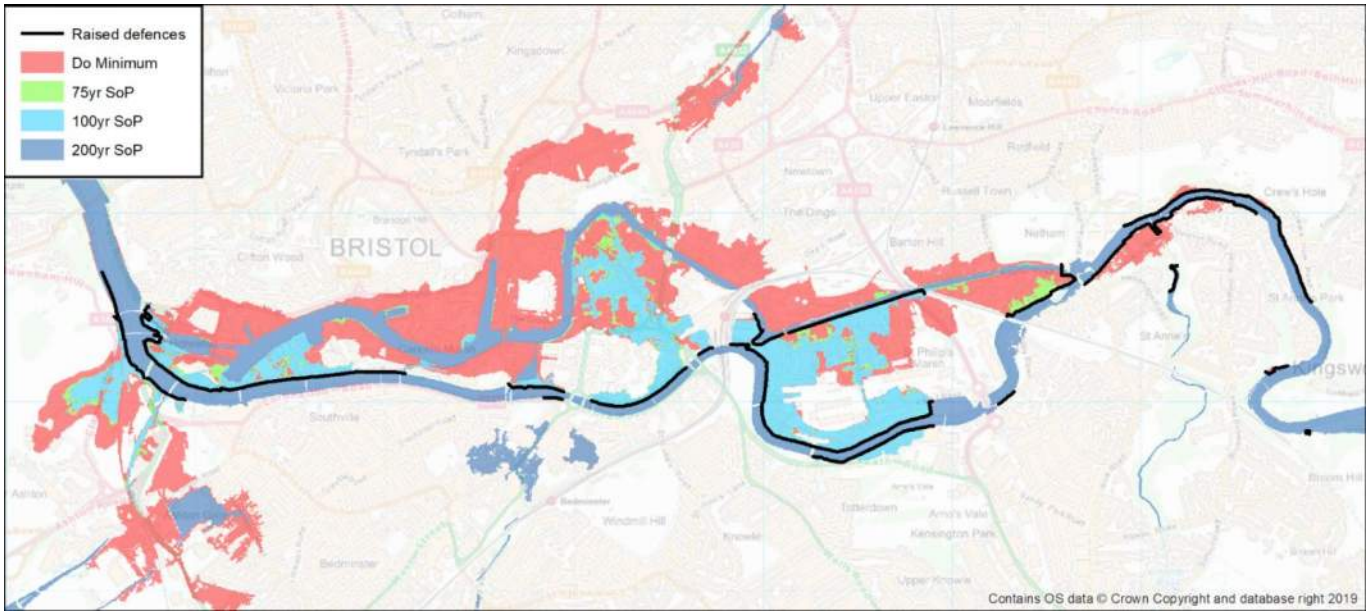


Figure 32: Flood extents of raised defences options vs Do Minimum for 2125 tidal 200yr event.

3.9.1 Risk of defence failures

The 2017 Strategy included a number of model runs to investigate residual risk, including those associated with defence breaches at locations along the raised defence alignments and at entrance points to the Floating Harbour. For the worst case design event, the flood risk during a 2115 200-year event with Entrance Lock gates failing lead to flooding in areas around Entrance Lock, Junction Lock, Victoria Street, Temple Back and St Philip's. Failure of the proposed gates at Netham for the same event showed flooding in Netham and St Philip's. The flood risk associated with the breaching of raised defences was also modelled extensively.

It should be noted that this modelling considered only tidal flooding and will require updating at future stages.

When the preferred way forward is implemented, the chance of failure of the defences will be greatly reduced compared with the present day, considering:

- New flood gates will be constructed with multiple levels of redundancy to protect against failure
- Most of the new defences are 'hard' defences (concrete walls, sheet piles or ground raising) and are generally not susceptible to failure

- Defences will be designed to accommodate loading from the design water levels plus a freeboard allowance for uncertainty. In practice this will lead to them being designed structurally for a larger event

To prevent the risk of manually operated gates being incorrectly deployed during a flood event, current operations procedures will require updating and refining following the implementation of the Strategy.

3.9.2 Risk of events greater than the design flood

The process for choosing the standard of protection for the proposed defences is explained in section 3.5.3. It should be recognised that the Strategy is unable to completely protect the city and surrounding areas from flooding, since larger, rarer events can always occur, however unlikely. This is to some extent mitigated by the provision of freeboard on the defences, which increase defence levels in practice.

Additional flood modelling was undertaken to determine the worst-case residual flood risk to the Bristol Temple Quarter site from overtopping. Residual risk was assessed for:

- fluvial events up to and including the 1 in 100-year flood event using the upper end climate change allowance or the 1 in 1000-year event not including climate change (current day), whichever is higher;
- tidal events up to the 1 in 1000-year event not allowing for climate change.

The residual flood risk modelling results were used to produce a suite of residual flood depth maps provided to the BTQ project for developing the site layout, including alignment of access and egress routes. This modelling has been used in the development of a ‘resilient access network’ as part of the BTQ strategic growth and regeneration proposals, ensuring that key access routes are protected against flooding.

Commercial Case

How will the strategy be delivered?

Figure 33: Example of integrated flood defences and public realm at Bath Quays

4 Commercial Case

4.1 Roles

BCC will lead the delivery of the Strategy in recognition of the potential impact and opportunity for the city, and the Strategy's interface with BCC's harbour, highway, planning, lead local flooding, coastal protection, civil protection and major landowner roles. The Environment Agency intends to delegate statutory powers for flood risk management works to Main Rivers to BCC, as necessary. The scheme elements pertaining to flood risk management will primarily be carried out under the Environment Agency's powers of Section 165 of the Water Resources Act, 1991. The Environment Agency will issue notices of entry under Section 172 of the Water Resources Act authorising BCC to enter land.

A Memorandum of Understanding is to be developed at OBC stage in advance of a legal agreement at FBC to formalise the roles and responsibilities of BCC and the Environment Agency in delivery of the Strategy. Such an approach has been successfully used to support the Derby City Council led, Environment Agency supported Our City Our River partnership project and lessons have been shared.

4.2 Regeneration and Development

The Strategy sets out a clear route map to deliver safe management of flooding across the city without increasing flood risk elsewhere. Throughout production of the Strategy, dependencies on which the strategy could become reliant have been identified and mitigated to avoid barriers to reasonable certainty of delivery.

A proportion of the defences interface with areas of growth and regeneration (discussed in 2.13). Proposals are at an early stage. Implementation is constrained and anticipated over the long term. The default budgeted approach of the preferred strategic approach is phased standalone flood defences typically delivered using Environment Agency's powers (i.e. avoiding Compulsory Purchase Orders). The Strategy avoids reliance on defences integral to new development, delivered over a period of time to a degree as the market dictates. However, integration of the defences into the urban landscape as part of developments offers many opportunities. BCC are focused on ensuring the flood defences will be integrated with high-quality public spaces in future developments wherever possible.

BCC plan to continue to work closely with the Environment Agency in order to ensure the Strategy has a reasonable certainty of delivery. This may include suitable planning instruments to support delivery of Phase 1 setting out how defences will be implemented and safeguarding land for delivery. Prospective developers will be provided with the details necessary to incorporate any mitigation / evacuation measures to address residual risks through information on requisite site-specific mitigation measures to be addressed in planning applications. Development would have to manage residual risk of an "extreme flood" or defence failures, possibly through evacuation or other plans and appropriate to the vulnerability classification of the proposed land use, or the emerging RAN strategy in St Philip's.

Where possible, integrating defences into development would ensure that the wider benefits of the scheme are realised. BCC will continue to lead on the regeneration aspects and work with developers to progress integral defences along with the implementation of the funding strategy and gaining further contributions. The Environment Agency are working closely with BCC planning teams to produce guidance for potential developers to ensure that future riverside development is undertaken in a manner which supports the principles of the Strategy and appropriately manages flood risk.

4.3 Maintenance

BCC currently operates the harbour flood stop gates as agents for and funded by Environment Agency who also maintain the raised tidal flood defences at St Philip's, Pill and Shirehampton. In practice, a significant part of the projected maintenance and operational costs for the Strategy are derived from the need to continue Floating Harbour operations and these costs would have been incurred anyway.

It is intended that the actual maintenance activities for the assets will be shared between the Environment Agency, BCC, and third-party owners who have incorporated flood defences within their developments. This will be on the basis of the most cost-effective way of providing the necessary maintenance, and via legal obligation of developers. Agreement over maintenance liabilities and responsibilities will be included in principle within the legal agreement between the two parties and will be clarified in an addendum to the agreement, developed as the final solutions are realised and constructed.

Bristol City Council has engaged with Sheffield and Derby City Councils learning from similar implemented schemes.

4.4 Phasing Plan

Phase 1 could be split into discrete packages and procured separately, especially at the FBC and construction stages. There may also be key elements in the different areas that need to be installed in advance and more complex areas which are likely to be delivered by BCC with support from Environment Agency. For example, the proposed flood gates at Entrance Lock and Netham which risk impacting on navigation and ongoing navigation; upstream and downstream raised defences interfacing with existing Environment Agency assets; raised defences along sections of the New Cut interfacing with highways, the railway and other BCC assets. However, sections of the Western Harbour and St Philip's frontages could be delivered by developers; delaying the build will maximise the chance of integration and developer-delivery. A review of the following impacts on the timing of the key reaches has been carried out, where a low risk of the impact leads to prioritisation of that particular area. The assessment is included in Appendix F.

- Reliance on other projects
- Abortive work
- Construction inefficiency
- Impairment of development opportunities
- Causes adverse impact

This has resulted in a suggested phasing priority of the works, shown in Figure 34.

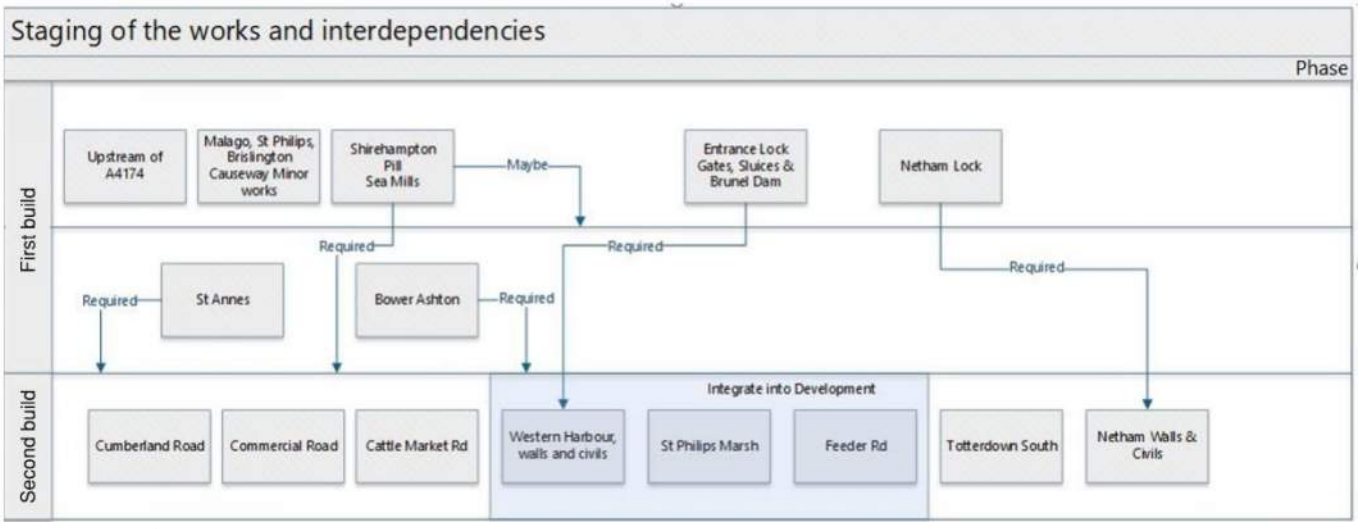


Figure 34: Phasing of the works

4.5 Procurement Strategy

Procurement of the Strategy schemes will first involve developing the Outline Business Cases (OBCs), then the detailed design, associated surveys and investigations, consenting, construction and supporting specialist advice and expertise required to successfully manage and deliver a major capital programme.

Although the Strategy has been developed as a strategic approach to a single benefit area (plus measures upstream or downstream to ensure no adverse impact), the scale of works required means that the recommended approach is

for OBCs to be developed for each of the two build stages identified in Section 4.4. Careful co-ordination will be required to ensure benefits are realised and not either double counted or overlooked for each phase.

The OBCs will develop the commercial case for delivery each package and alignment with other ongoing programmes and projects. There are multiple approaches, either as one package or as a number of discrete packages, including but not limited to the following options:

- a traditional design-bid-build,
- a specialist design and build contract,
- incorporating the works as part of developer-led works.

An overview of the different procurement approaches is provided in Table 19. All procurement routes have potential advantages and disadvantages which will need to be carefully managed.

Approach	Advantages	Disadvantages
Traditional (design-bid-build)	Quality; full design pretender Design flexibility, variations and instructions Specialist subcontractors Design control Cost; there may be a lump sum cost benefit unless multiple changes are made	Time; requires full detailed pack pretender Cost; not a benefit if many changes are made once the design is tendered.
Design and build	Time; fast track, overlap of design and construction Cost; lump sum / guaranteed maximum price Single point of responsibility; contractor design and build responsibility Innovation; can benefit quality Low risk for the client Named subcontractors; Early contractor input to design	Quality; cheapest route to meet contract specification can lead to low quality products / build quality Design flexibility; request for changes will have high cost / time implications Can end up paying for risks which are not realised. Need to develop the design to a significant level where the contract with the contractor can be let without passing over too much risk as this will drive the costs up.
Developer led	Reduced responsibility for BCC to manage Defence levels can still be met	Less control over solution. Lack of design flexibility Programme outside of Environment Agency control Greater complexity for assurance, inspection and maintenance

Table 19: Potential procurement approaches

The procurement of any services and works associated with delivery, operation and maintenance of the schemes will follow BCC contract procedure rules to ensure compliance with relevant legislation.

The strategy developed as part of each OBC will need to be flexible to:
- allow different procurements routes to be considered,
- integrate with wider development and funding opportunities, and
- prioritise flood risk mitigation in the context of the overall flood risk strategy.

4.6 Contractual terms and risk allocation

Appropriate contractual terms are important to minimise (or allocate) risk during the term of the contract. Contractual terms for the detailed design and construction of the schemes will be established during or after the OBC stage.

4.7 Procurement route and timescales

There are a number of different routes to market that are capable of delivering the needs of the scheme. These and the associated timescales will need to be considered at the OBC stage but for information a selection of the potential routes are listed below:

- Bespoke tender
- Scape Procure – Civil Engineering and Infrastructure Framework (Scape Framework)
- EA Collaborative Delivery Framework

The potential value of early contractor involvement (ECI) has been noted and should be considered to allow increased input to areas of the design from a buildability perspective, as well as allowing for continuity between design and construction.

The anticipated provisional timescales for the next stage of work are set out in the list below:

- Spring 2021: Key decision on SOC and Environment Agency endorsement
- Summer 2021 onwards: Develop OBCs
- 2022 onwards: Detailed design, consenting and delivery

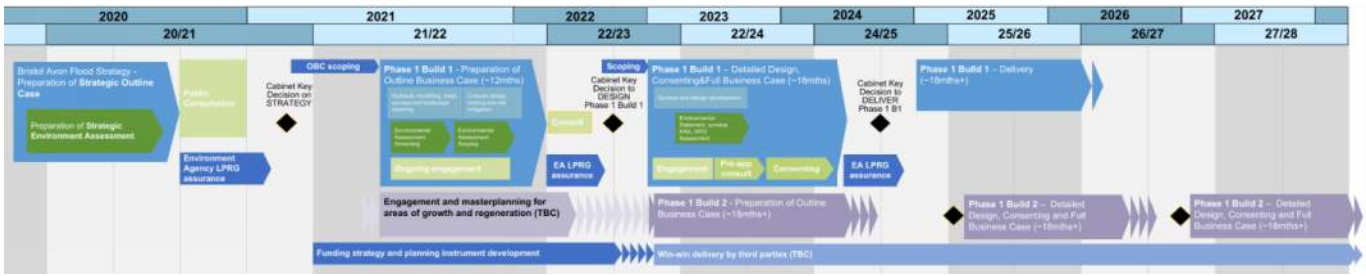


Figure 35: Indicative Strategy delivery timeline

4.8 Efficiencies and commercial issues

Identifying and realising efficiencies will be an integral part of the delivery of the scheme, with an aim to deliver 15% efficiency savings on the overall scheme costs (as per the DEFRA target for efficiency savings). Some opportunities for potential cost savings are given in the Updates to Proposed Defences report[34]. Efficiencies will be explored at the OBC stage.

[34] Arup, "Updates to Proposed Defences", 2020

Financial Case

How will it be funded?

Figure 36: Flood defences including glass panels installed in Upton upon Severn

5 Financial Case

5.1 Financial summary

The total Net Present Value (year 2025) cost of the scheme is as broken down in Table 20. Maintenance costs take account of two major repairs to defences or locks over the lifetime of the scheme, assumed to occur at year 33 and year 67 of scheme life, as well as annual maintenance to both.

	Costs (£m)
Capital works, 2020s	216
Capital works, 2060s	9.1
Whole life maintenance	24.3
Whole Life Costs	**249.3**

Table 20: Breakdown of Strategy costs NPV 2025

The scheme costs include a 60% optimism bias (except for elements of the Cumberland Road works which are based on a reduced optimum bias as the actual construction cost for the ongoing wall repairs are known), but also have been progressed to a high level of detail for this stage of assessment, taking account of recent tenders in the locale. The scheme hydraulics exhibit relatively low levels of variation, and therefore the designs are relatively insensitive to changes in key assumptions. There may therefore be strong potential to review the costs at a later date, and sensitivity in the costs may be considered in the range +/-15% (£32m capital works costs, 2020).

Areas	**Reach Title**	**Total CAPEX Cost in 2024 (2019 equivalent + Optimism bias)**	**Total CAPEX Cost in 2065 (2019 equivalent + other Costs & Fees + Optimism bias)**
Western Harbour	Entrance Lock / Western Harbour	£ 27,032,723	£ 4,886,442
Western Corridor	Cumberland Road	£ 63,466,813	£ 2,499,894
Western Corridor	Cumberland Rd East Defence	£ 382,536	£ -
Western Corridor	Commercial Road / Bathurst Dam	£ 10,799,348	£ 1,434,559
Western Corridor	Clarence Road	£ 18,242,305	£ 2,383,973
Eastern Corridor	Cattle Market Road	£ 3,105,727	£ 767,446
Eastern Corridor	St Philip's Marsh Defences	£ 23,600,926	£ 5,485,890
Netham Lock	Netham Lock	£ 13,865,431	£ 2,204,006
Western Harbour	Bower Ashton	£ 5,104,481	£ 1,606,350
Eastern Corridor	Totterdown South Defences	£ -	£ 1,381,459
Feeder Road	Feeder Road	£ 7,178,225	£ 2,790,812
St. Anne's	St. Anne's North Bank	£ 18,391,068	£ -
St. Anne's	St. Anne's South Bank	£ 12,119,340	£ 1,319,928
Works to prevent adverse impacts	Downstream, City Centre and Upstream of A417	£ 12,663,040	£ 7,651,435
Total		**£215,951,964**	**£34,412,194**

Table 21: Breakdown of scheme Capex costs by reach including optimism bias

5.1.1 Strategy development costs

For the development of the SOC, BCC have contributed £935k up to February 2021, and the Environment Agency have contributed £384k. An estimate of required costs for the Outline Business Case for Phase 1 Build 1 is given in Table 22:.

OBC section	Assumptions	Build 1 OBC Estimate (£k)	Build 2 OBC Estimate (£k)
Outline Business Case	Prepared using evidence base from SOC supplemented by below. Intrusive survey and consenting during subsequent Technical Design.	40	40
Flood modelling	Update of climate change allowances to reflect changes in guidance. Modelling updates including ground level LiDAR data, representation of flow pathways between flood sub-cells during high magnitude flood events. Improvements to the representation of Pill, Shirehampton and Sea Mills. Improvements to modelling to finalise works to ensure no adverse impact upstream of the A4174 and works adjacent to the Malago.	100	25
Develop reference design - flood scheme	Least cost outline reference design (Design and Build route, with contractor to subsequently obtain planning). Concept design of piled solution for Knuckle and Netham, and works to ensure no adverse impact.	80	
	Wide range of approaches dictated by wider contracting/risk ownership. Least cost outline reference design (Design and Build route, with contractor to subsequently obtain planning). Concept design optimising existing design for Western Corridor.		120
Develop reference design - public realm	Range of approaches, from no-extra over (from consentable strategy) to integrated and high value public realm. Potential for delivery routes via masterplan areas.	20	30
De-risking strategy	Site constraints and access including liaison and discussion with leaseholders and landowners to influence layouts/approach including working areas. Utility review, engagement and outline mitigation strategy.	30	65

OBC section	Assumptions	Build 1 OBC Estimate (£k)	Build 2 OBC Estimate (£k)
Site investigation	Significant GI collated from other projects for other purposes. Recommend delay until Technical Design stage. Some banks/structures have ground-risk and an SI and assessment will help to finalise the approach and de-risk the solutions. Prioritised surveys to include topographic to refine works to prevent adverse impacts; prioritized SI at Knuckle and Netham (boreholes and cores).	80	120
Contractor involvement	Increased preferred solution cost uncertainty	15	20
Stakeholder engagement	Significant engagement needed but only to outline level. BCC to lead. Consultation on the preferred option to establish case for design.	20	50
Environmental assessment	Baseline data review, programming future surveys, assessment of Phase 1 first build stage impacts to scope mitigation, statutory meetings and engagement.	50	50
Funding strategy	Business case financial case development including liaison with partners, agreements and viability assessments. Economic case currently focused on Flood Defence Grant in Aid and nominal allowance for work to expand justification around wider benefits to align with funding partner requirements.	30	30
Planning	Option favoured by project team is to exclude completely, given need for detail not available until Technical Design. Full planning could exceed £250k plus Technical Design informed by surveys. Develop consenting strategy including early planning engagement and agreement over approach (noting option of Hybrid application)	20	20
Legal Agreement	BCC and Environment Agency to prepare Memorandum of Understanding setting out expectations and requirements for delivery of OBCs.	40	10
BCC PM including managing project interfaces with BTQ and WH.	15%	76	87

OBC section	Assumptions	Build 1 OBC Estimate (£k)	Build 2 OBC Estimate (£k)
Risk contingency	• Citywide engagement as phase 1 build stages are refined and development. • Allowance for active travel and public realm integration beyond flood defence requirements. 60%	348	400
TOTAL		**929**	**1,067**

Table 22: Estimate of OBC costs

5.2 Funding Sources

5.2.1 FCERM Grant in Aid

Partnership funding means that the costs of flood and coastal risk management projects are shared between national and local sources of funding. Under the 2020 'Flood and Coastal Erosion Resilience Partnership Funding' policy, eligibility for central government FCERM Grant in Aid depends on the benefits and outcomes of the FCERM project. If the eligible GiA does not cover all costs, scheme promoters need to raise extra money from partners through contributions. The Partnership Funding calculator is the tool used to calculate the Partnership Funding (PF) score of a potential project, to show the maximum amount of Flood Defence Grant in Aid funding available.

The scheme benefits considered in determining the Grant in Aid contribution are:
- Flood damages avoided, in terms of their impact at a national level
- Flood impacts to people
- Households better protected against flood risk, in each deprivation category, including with impacts of climate change
- Statutory environmental obligations met, in terms of habitat creation and improvement

In order to qualify for this funding, the Adjusted PF score must be 100% or above, and due to the high demand for this funding only those schemes with higher scores are likely to be prioritised. If the funding for a scheme is reliant on the maximum available government funding, with the remainder provided by third parties, then the Adjusted PF score will be limited to 100%; to increase this, it is necessary to seek a greater percentage of third-party 'partnership funding'.

Present value FCERM Grant in Aid towards up-front costs are given as £68.5m. It should be noted that GiA does not cover maintenance and operational costs and these will need to be met by BCC. In practice, a significant part of the projected maintenance and operational costs for the Strategy are derived from the need to continue Floating Harbour operations and these costs would have been incurred anyway.

It has been assumed in the calculator that, to allow for pluvial flood risk, only 90% of properties have been claimed. 90% reflects the approximate proportion of properties in the fluvial and tidal flood plain that are also subject to pluvial flood risk.

5.2.2 Additional sources of funding

The Grant in Aid funding identified at this stage for this scheme has been identified at a maximum of £68.5m, requiring funding of £147m to be secured for Phase 1. This does not include placemaking costs which could add an additional £20m. The Grant in Aid estimate would need to be reviewed and updated at the Outline Business Case stage. Additional available sources of funding are identified below. This was discussed in the Outline Funding

Strategy[35], which was produced as part of the 2017 Study, but the below conclusions have been updated to reflect subsequent changes.

Identified in principle

- The Local Enterprise Partnership (LEP) Economic Development Fund (EDF) has a programme allocation of £5m in 2023 and £5m in 2033. Seeking further funding from this source could be explored but given that the EDF is fully subscribed this could only be via a substitution with other BCC programme allocations.

- BCC has funded the £9m 2020 Cumberland Road Stabilisation Works, required to deliver the flood defences, by prudential borrowing under the Approved Capital Programme. This will be evidenced and claimed as partnership funding.

To be secured

- A contribution to strategic flood defences could come from the Community Infrastructure Levy (CIL) subject to reconciling with the needs of other infrastructure projects.

- A Local Levy contribution will be sought from the Wessex Regional Flood Defence Committee (WRFFC) to support production of the first phase OBC. The Local Levy is a locally raised source of income used to support the WRFFC, fully funded Local Levy flood risk management projects as well as acting as contributions towards schemes under DEFRA's partnership funding policy. The level of funding available to support delivery of the Strategy schemes could be significant.

- Potential contributions from developers / landowners / beneficiaries recognising BCC's significant land ownership of the areas proposed for defence works and potential for capital receipts, particularly in the area of Western Harbour. Contributions could take the form of developer bonds, business rates, local levy, business rate retention.

- The West of England Combined Authority (WECA); Bristol and other Councils in the west of England are progressing a devolution deal with the Government to lever an additional £900m of investment over the next 30 years. There is potential for the Devolution funding to help deliver the flood strategy, which in turn, will assist in the delivery of the city's housing and economic growth strategy. Opportunities include transport and green infrastructure.

- A Business Improvement District (BID) could provide an opportunity to secure monies from harbourside businesses. Support is likely to be greatest for the BID to fund targeted public realm enhancements, noting BIDs require ongoing extensive administration and renewal.

- The Coastal Communities Fund should be investigated by BCC to make a case for submitting an expression of interest; flood defence schemes have received funding in the past.

- The Local Growth Fund via the Growth Deal could also be explored particularly if this was of a scale with potential to dovetail into the forward programme e.g. be ready to take up any available slack arising from slippage elsewhere.

- Central Government grant funding to support regeneration and associated enabling infrastructure.

- Growing Places Fund/Revolving Infrastructure Fund. (Bath Quays was funded using the Revolving Infrastructure Fund from the LEP).

- National Lottery Heritage Fund.

- Sustrans – contribution to improved cycle network

- Developers absorbing delivery costs if integrated within development fabric.

[35] AECOM, Outline Funding Strategy, 2017

An indicative illustration of potential funding contributions for the preferred strategic option for works in Phases 1&2 is provided in Table 23. Note that potential sources of funding are still under review with BCC negotiating further with other parties.

Going forward it is recommended that liaison and dialogue with the Environment Agency's local and national investment and funding specialists is carried out to provide assurance on the funding baselines. Until this discussion with LRPG is held, the amounts of GiA funding stated in this report should be considered preliminary and in need of confirmation, in conjunction with serious investigation into the potential alternative sources of funding needed. At OBC stage it is recommended that the partnership funding calculations are revisited.

Contributor	Potential Contribution (£m)	Notes / Assumptions
Flood Defence Grant in Aid	£68.5m High	Subject to LPRG assurance and outcome of Partnership Funding Calculator. Focus on better protecting existing homes and businesses present day an in 2040
LEP EDF	£10m Medium	BCC borrowing to be repaid by the EDF sourced from business rate uplift. Programme level commitment pending LEP OBC acceptance. Allocations of £5M in 2023 and £5M in 2033. Business Rates Levy? Business rates retention?
Prudential borrowing - committed	>£9m Medium	£9m Cumberland Road stabilisation works contribution & cost avoided (2020)
WRFCC Local Levy	Low	Funding to support business case development. Allocation, subject to WRFCC approval for OBC development £500k 2021-2022 and £156k 2022-2023. *£290k 2017-2018 and £94k 2020-2021 for study (sunk costs)*
Enabling Infrastructure funding	High	Infrastructure levies, BTQ, Western Harbour Developer Bonds and mechanisms to capture land value uplift/ business rates/ levy / retention/new housing credits/user charges/ tax increment financing.
CIL	Medium	Approximately £3.5m available for strategic infrastructure annually, subject to ongoing CIL commitments.
BCC Reserves	Low	*£469k 2014-2017 and £300k 2018-2020 for strategy (sunk costs)*
Borrowing	Large	Prudential or equivalent including state infrastructure banks

BID	Medium	Subject to successful implementation of BID. Support is likely to be greatest for the BID to fund targeted public real enhancements, noting BIDs require ongoing extensive administration and renewal.
Community Groups	Low	Sustrans, heritage groups, biodiversity groups, museums etc
Coastal Communities Fund	Low	
Devolution Deal	Medium	£900m found over 30 years. Composition of programme to be confirmed and likely oversubscribed.
Other sources	TBC	Central Government grant funding to support regeneration and associated enabling infrastructure. Developers absorbing delivery costs if integrated within development fabric. Heritage Funding – e.g. Natural Lottery Department of Education to safeguard schools (St Mary Redcliffe) Active Travel Funding Crowd funding Additional climate emergency state grants

Table 23: Potential funding contributions. Key: Low ≤ £1m <Medium ≤ £10m < High

Management Case

How will it be managed?

Figure 37: Overtopping at Junction Lock during March 2020 tidal surge

6 Management Case

6.1 Introduction

The Strategy will be submitted to the Environment Agency for endorsement, following assurance by the Large Project Review Group (LPRG).

6.2 Phase 1 management

This management case sets out the first phase of construction works planned for 2025 onwards. Phase 2 is proposed to be constructed in 2065, and thus proposing management arrangements at this stage is not appropriate.

However, reviews of the Strategy are proposed at least every twelve years to review the latest observations and projections of the impact of climate change on River Avon flood risk predictions. The reviews will enable BCC and the Environment Agency to determine the timing and form of Phase 2 when the magnitude and rate of sea level and peak river flows increase can be better determined.

6.3 Project management

6.3.1 Project structure and governance

The Strategy delivery will be managed by BCC, supported by the Environment Agency. Roles and responsibilities are outlined below.

6.3.2 Project board

A multi-agency Project Board comprising senior management representation from BCC, the Environment Agency and supplier(s) will provide direction and management for the Strategy's implementation. The board will give direction for the Strategy and be accountable for its success. The board will have sufficient authority to carry out their responsibilities effectively. Membership from the Environment Agency and BCC includes flood risk, planning and development, city docks, estates, harbour and regeneration. The collective responsibilities of board members include:

- Accepting and demonstrating ownership of the Strategy.
- Working as a team to provide collective and unified direction.
- Effective delegation with appropriate project tolerances and exception management processes.
- Facilitating cross functional working ensuring that the project structure is recognised and respected by line management.
- Supporting development and delivery of the funding strategy.
- Committing all of the resources required to successfully complete the project.
- Effective decision-making including risk, issue and change management.
- Project assurance and quality control.
- Ensuring timely and effective communication within the project and with external stakeholders.
- Ensuring the Strategy deliverables are reliable, sustainable and can be maintained effectively.

6.3.3 Steering group

Overseeing the Project Board will be a Steering Group (comprising representation from BCC and the Environment Agency) and a Strategic Board. This governance structure will provide appropriate interface management with parallel projects such as BTQ and Western Harbour, as shown in Figure 38: Management structureFigure 38.

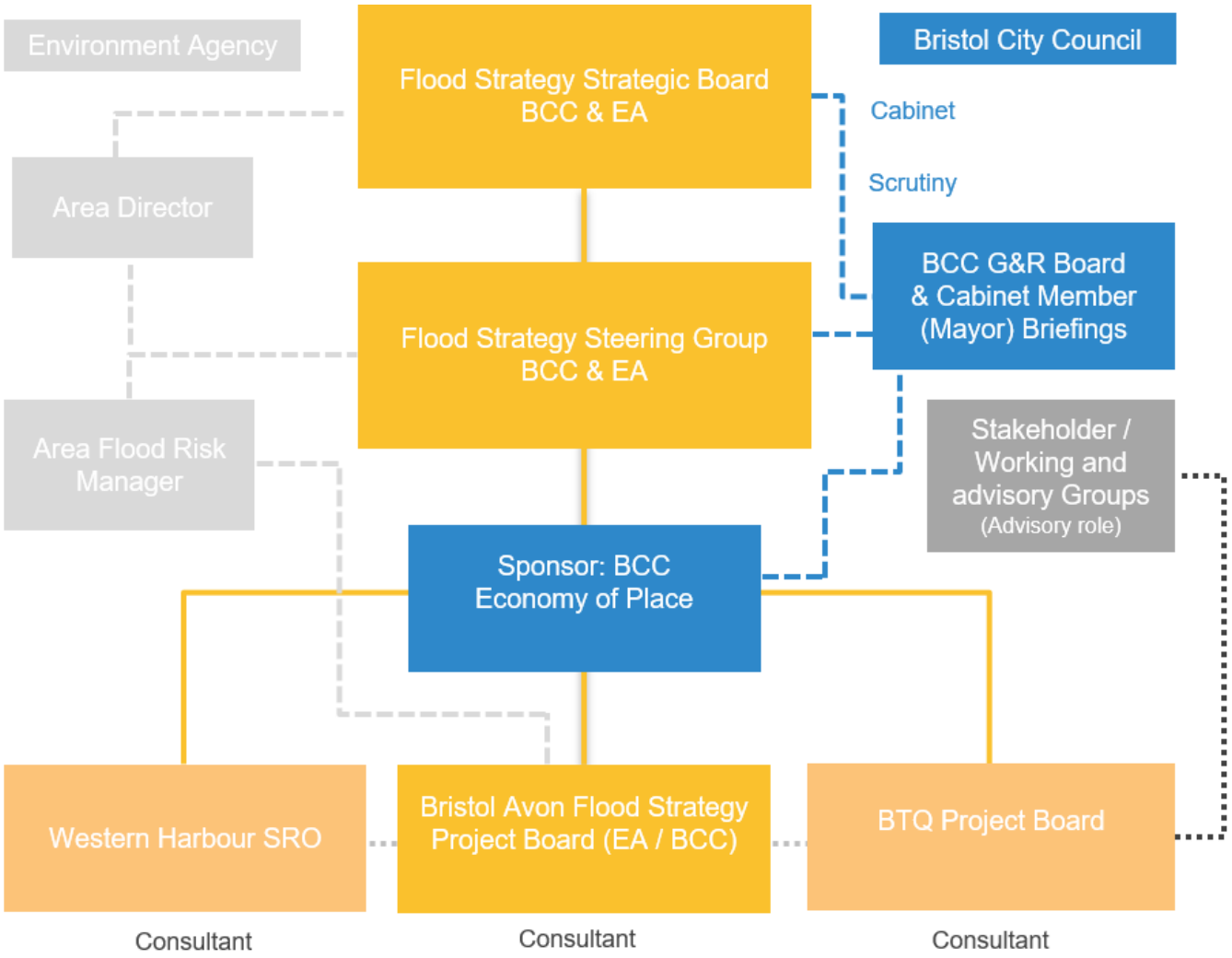


Figure 38: Management structure

6.3.4 Decision making

Decisions will be made through the three-tiered central governance of Project Board, Steering Group and Strategic Board. These currently meet monthly, bi-monthly and by exception respectively.

The Steering Group is the senior decision-making forum represented by BCC's Executive Director for Growth and Regeneration and the Environment Agency's Area Flood Risk Manager supported by officers. The Strategic Board is formed by the Mayor or delegated cabinet member and the Environment Agency's Area Director.

It is also noted that both the Environment Agency and BCC have their own decision-making pathways. These will be followed to ensure appropriate internal officers and members are well informed of the decisions that are to be taken at each level. BCC's Economy of Place Director takes responsibility for managing the interfaces as Sponsor.

6.3.5 Project manager

The Board will be supported by a team led by a dedicated Project Manager who has the authority to run the projects to deliver the Strategy on a day-to-day basis on behalf of the Project Board. The Project Manager's primary responsibility is to ensure that the project produces the required outcomes to the required standard of quality and within the specified constraints of time and cost.

6.3.6 Project representative

The Environment Agency provide a Project Representative from the Wessex Area team to work with BCC on a weekly basis to represent the interests and requirements of the Environment Agency and provide general advice for

delivery of the Strategy. This time will not be charged directly to the Strategy. Advice from the Environment Agency cost and carbon lead, NEAS, modelling, legal or other specific advice from will be charged to the Strategy and funded through Local Levy.

Other statutory bodies with an interest in the Strategy (specifically Historic England, Natural England, Wessex Water, and neighbouring risk management authorities as well as BCC and Environment Agency in their role as regulators) support through a stakeholder working group

6.3.7 Project roles and responsibilities

Specific roles for the Strategy are subject to change but listed below:

- Project Sponsor - Nuala Gallagher
- Senior Responsible Officer - Adam Crowther
- Project Executive – John Roy
- Project Manager - Robin Campbell
- EA Project Representative - Deborah Steadman

6.3.8 Project plan

The following milestones have been agreed at a high level for the SOC and OBC stages of the Strategy. Further detail of the programme will be supplied at OBC.

- Consultation: Early Autumn 2020
- EA assurance (LPRG) Autumn 2020
- Executive Director Meeting: November 2020
- Corporate Leadership Board: November 2020
- Strategic key decision: February 2021
- Phase 1 Build 1 OBC development: 2021-22
- Phase 1 Build 1 design and consenting: 2023-24
- Phase 1 Build 1 construction: 2024 onwards
- Phase 1 Build 2 OBC development: 2022-24 (incorporating engagement and masterplanning for areas of growth and regeneration)
- Phase 1 Build 2 design and consenting: 2025-26
- Phase 1 Build 2 construction: 2027 onwards
- Supportive planning instruments: 2021 onwards, subject to Local Plan

The Strategy interfaces with many projects and programmes. Phasing of the proposed construction works is discussed in 4.4.

6.3.9 Communications and stakeholder engagement

Statutory stakeholder engagement

Stakeholder engagement with statutory bodies has helped shape early technical stages of Strategy development. These include BCC, Environment Agency, Natural England, Historic England, North Somerset, South Gloucestershire, Bath & North East Somerset and Wessex Water.

The organisations have formed the stakeholder working group who meet regularly to provide assurance and support to the project team. Emerging work is shared for observation and information.

Public engagement and consultation

In Autumn 2020, public consultation is planned to inform BCC's decision-making to adopt the Strategy, specifically Cabinet approval, and subsequent stages. The consultation will raise awareness on the need for the Strategy and seek views on the leading strategic approach. BCC will work with neighbouring authorities to ensure that the communities affected by the proposals outside of Bristol are also appropriately consulted. Views on alternative strategic approaches that are not proposed will also be invited. BCC Cabinet will be asked to take a decision on the Strategy once consultation has been analysed and incorporated into the Strategy.

Specific objectives of the consultation are:

- To create understanding of the need for the Strategy and the benefits it will bring to the city.
- To seek the views of local people, businesses, stakeholders and developers about the preferred strategic approach outlined in the strategy, placemaking opportunities and to ensure that they have the opportunity to comment on the approaches that the council is proposing not to take forward.
- To ensure that those outside of Bristol who may be affected by flood measures in their areas are adequately consulted.
- To ensure citizens and stakeholders have the opportunity to comment on other options that the council is not proposing to take forward.
- To ensure that consultees understand how flood measures can be successfully designed into developments and create opportunities for placemaking.
- To consult on the Strategic Environmental Assessment.

Consultation plans have been constrained due to the ongoing pandemic and are limited to online material and events, complemented by direct mailings to harder to reach communities. To complement the formal consultation, events will be held with interested groups to understand the issues and opportunities in more detail including:

- Interested communities / individuals
- Developers and businesses
- Advisory groups
- Interested groups such as civic, architects, engineers and others

Further rounds of engagement and consultation are planned as the first phase of the Strategy progresses to design, consenting and construction. For example, when initial designs are drawn up to help develop the proposals at a local level. Feedback will inform the case and then design of the first phase of measures.

6.3.10 Change management

Robust change management control procedures will be used for the OBCs and detailed design and construction phases of the schemes, managed by exception.

Project changes will be agreed with the Project Board to ensure consistency in reviewing all project changes and also whether there is a need to implement the change.

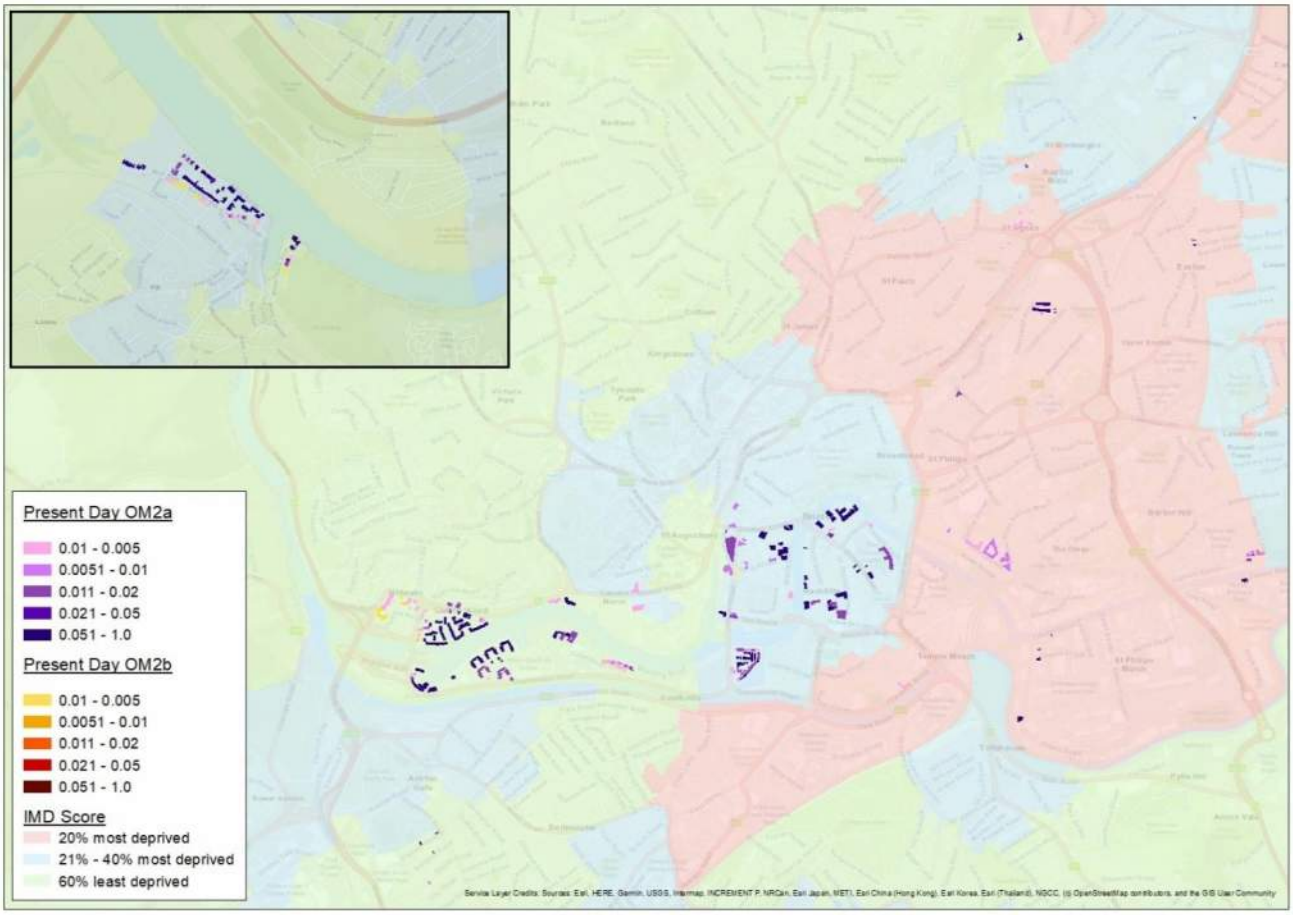
6.3.11 Benefits realisation

The realisation of benefits will be managed by BCC in their capacity as the lead organisation for delivering the Strategy. All benefits will be realised when construction works have been completed. The location of the households moving to lower flood categories (in relation to OM2) is shown in Figure 39. The number of properties are:

- **Households moved out of any flood probability category to a lower category:** 581
- **The number of households for which the probability of flooding is reduced from the very significant or significant category to the moderate or low category**: 375
- **The number of households in the 20% most deprived areas moved from the very significant or significant flood probability category to the moderate or low category:** 219

The first phase works are currently expected to be completed between 2025-27 (as per Figure 6) and therefore BCC will report the realisation of benefits at that time.

Ongoing realisation of benefits will be achieved through a co-ordinated response to ensure flood gates and lock gates are closed prior to future flood events. This will be achieved by continuing forecasting of flood events and asset operations.



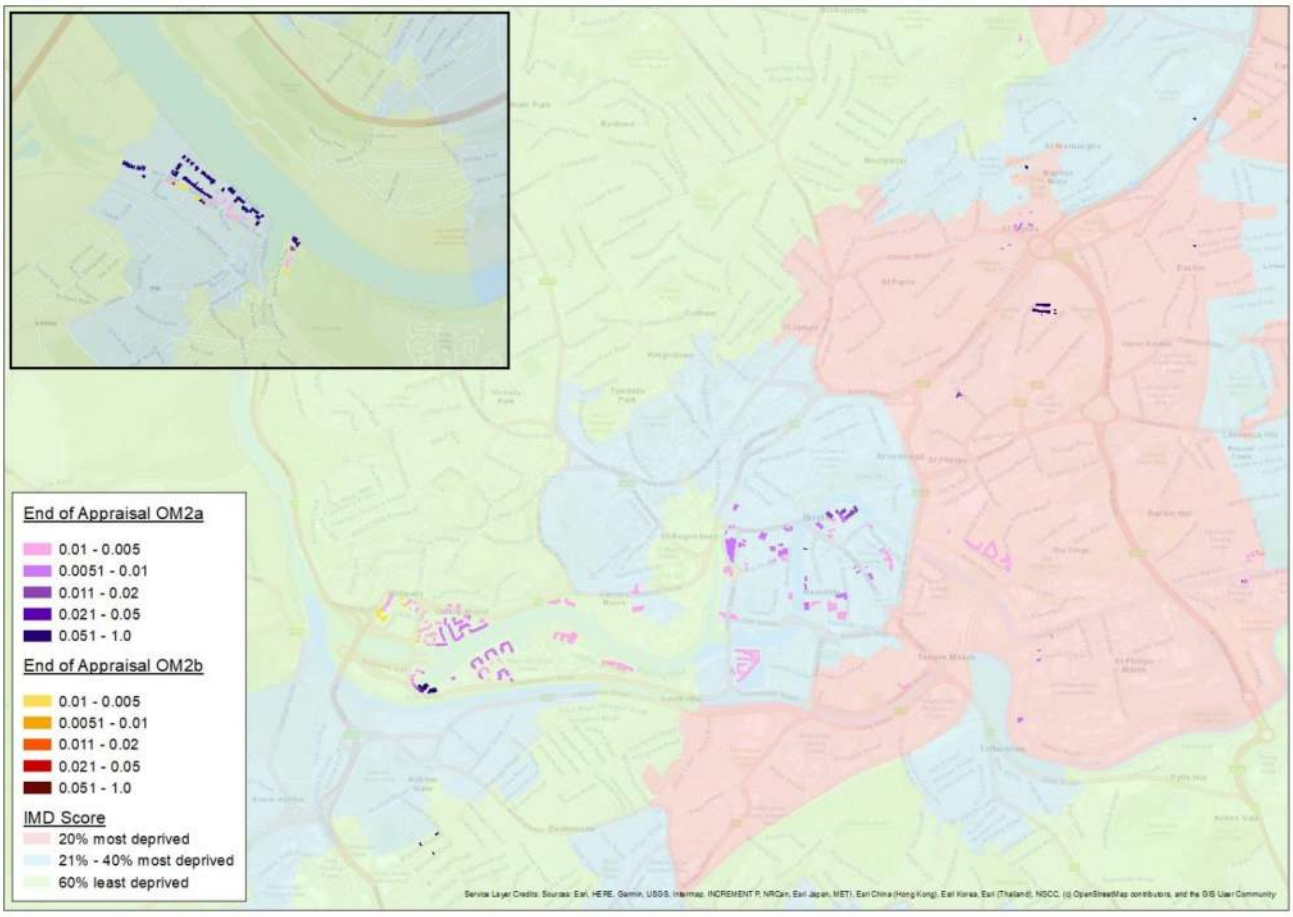


Figure 39: Shows the change in flood probability for households in the present day (above) and at the end of the appraisal period (below)

6.3.12 Risk management

The key delivery risks for the Strategy are summarised in section 2.10. Refer to the risk register included in Appendix G for more information.

6.3.13 Safety plan

Public health and safety elements will form a key consideration in scheme development, will be considered throughout further design stages and will form part of the designer's risk assessment. This will be continued through detailed design with any residual risks included in the Health and Safety file.

Consideration will be given to the Construction (Design and Management) Regulations (CDM) and key health and safety issues as the preferred strategy is advanced through the development of OBCs and detailed design stages. Designer risk assessments will be written, and appropriate records will be kept throughout future stages of the schemes. Where risks are identified that cannot be resolved entirely then appropriate mitigation measures will be developed wherever possible to reduce the probability of the risk occurrence.

Public Safety Risk Assessments (PSRAs) will be carried out prior to any work starting on site to ensure the safety of the public during and after construction.

A health and safety file will be produced for all stages of a scheme to ensure that the operation and maintenance of any built asset can be carried out safely.

6.3.14 Safety of harbour management

An essential component of the strategy is the installation of new flood gates at the upstream and downstream ends of the Floating Harbour. The gates will require routine operation and with this brings operational safety risks. BCC Harbour Authority will operate these gates, in the same way as they operate the existing harbour gates by agreement with the Environment Agency by way of a memorandum of understanding.

This sets out the funding provisions by the Environment Agency, and also sets out the expectations of both parties associated with operation, including the requirement to use every endeavour to perform the works with due skill, care and diligence, and to the highest appropriate accepted standards of public sector accountability. Appropriately trained personnel are to be made available by the Authority to carry out the works. By continuing with these approach, adequate safety protocols will be ensured for the operation of the new gates.

6.3.15 Contract management

Contract management for the OBCs and detailed design / construction will be delivered in accordance with the BCC procedures ensuring compliance with all relevant legislation.

6.3.16 Assurance

The governance structure laid out in Section 6.3.1 will be responsible for project assurance for the OBCs and following stages of work. Due to the scale of work required over the lifetime of this strategy, we will be seeking assurance from the Environment Agency's Large Project Review Group for this strategic outline case, the outline business case(s) and the full business case(s). This will complement the BCC scrutiny process including the Growth and Regeneration Scrutiny Commission and the current inquiry into climate adaption.

6.3.17 Post project evaluation

Upon closedown of the OBCs and detailed design / construction projects a post project evaluation will be completed. This will be to verify that all objectives are met, the intended benefits realised, and lessons learnt are captured and shared with the Project Board.

Reviews will be carried out periodically during the development stages.

6.3.18 Contingency plans

BCC Civil Protection Unit are in the process of reviewing their city centre emergency plans for flooding from the River Avon. The BCC Harbour Operational Protocol is well-established and constantly reviewed for improvements, such as the recent communications protocol for Netham lock gates / dam sluices to complement those on the Eastville sluices. Contingency plans will be established during the OBC stage of the scheme delivery.

6.4 Alternative delivery approaches

Although the early build out of the flood defences can easily be addressed through the above management approach, which is summarised in Figure 40, the later build out elements (build 2) may need different mechanisms to both fund and deliver.

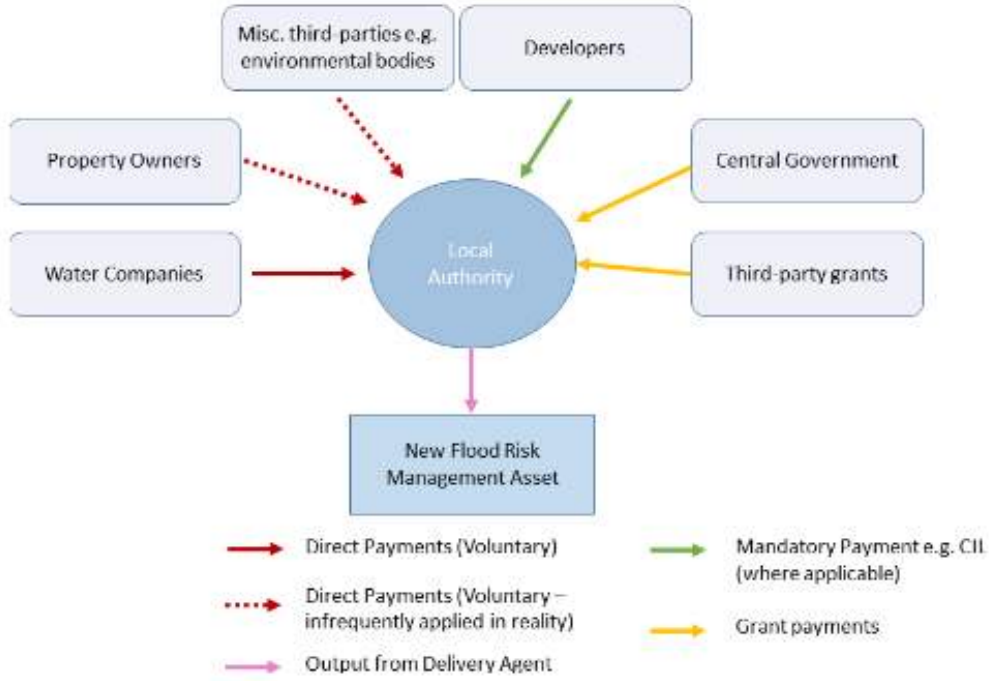


Figure 40 Existing business model for flood risk management[36] ©

The flood defence adjacent to St Philip's Marsh is complex with multiple landowners who have a significant drive to see the defences installed as it will benefit land value and unlock development, whilst Western Harbour is wholly owned by BCC but is more sensitive from a heritage, operation and consenting point of view. As plans develop for the more complicated areas such as Western Harbour and St Philip's Marsh, alternative funding and delivery approaches can be considered. An example of alternative business models is set out below (Figure 41) and summarised in Table 24:

Business Model	Description	Advantages
Stakeholder delivery	A local enterprise partnership is formed and comprises local businesses, property owners, insurance companies, developers, sewage undertakers, other catchment users and local authorities including BCC as the lead. This organisation would have the ability to enter into	• Reduced taxes • Meaningful stakeholder input • Local pooled resources avoids failure

[36] Walsh et al. (2016), *Alternative business models for flood risk management infrastructure* [online] accessed at: https://www.e3s-conferences.org/articles/e3sconf/abs/2016/02/e3sconf_flood2016_20015/e3sconf_flood2016_20015.html

	relationships to enable the financing of the flood risk management project.	
Financing through full cost recover	Private sector recovers cost of providing financed flood risk management	• In longer term reduced requirement for insurances /compensation pay out • Can adapt indirect user charges to suit phased approach
Financing by developers/landowners	Initial outlay paid by various landowners through savings, loans or subsidiaries. As compensation they receive a reduction in bills, home insurance premiums and an increase in property prices	• Simple • Helps unlock funding • Easy to control

Table 24: Business Model Options

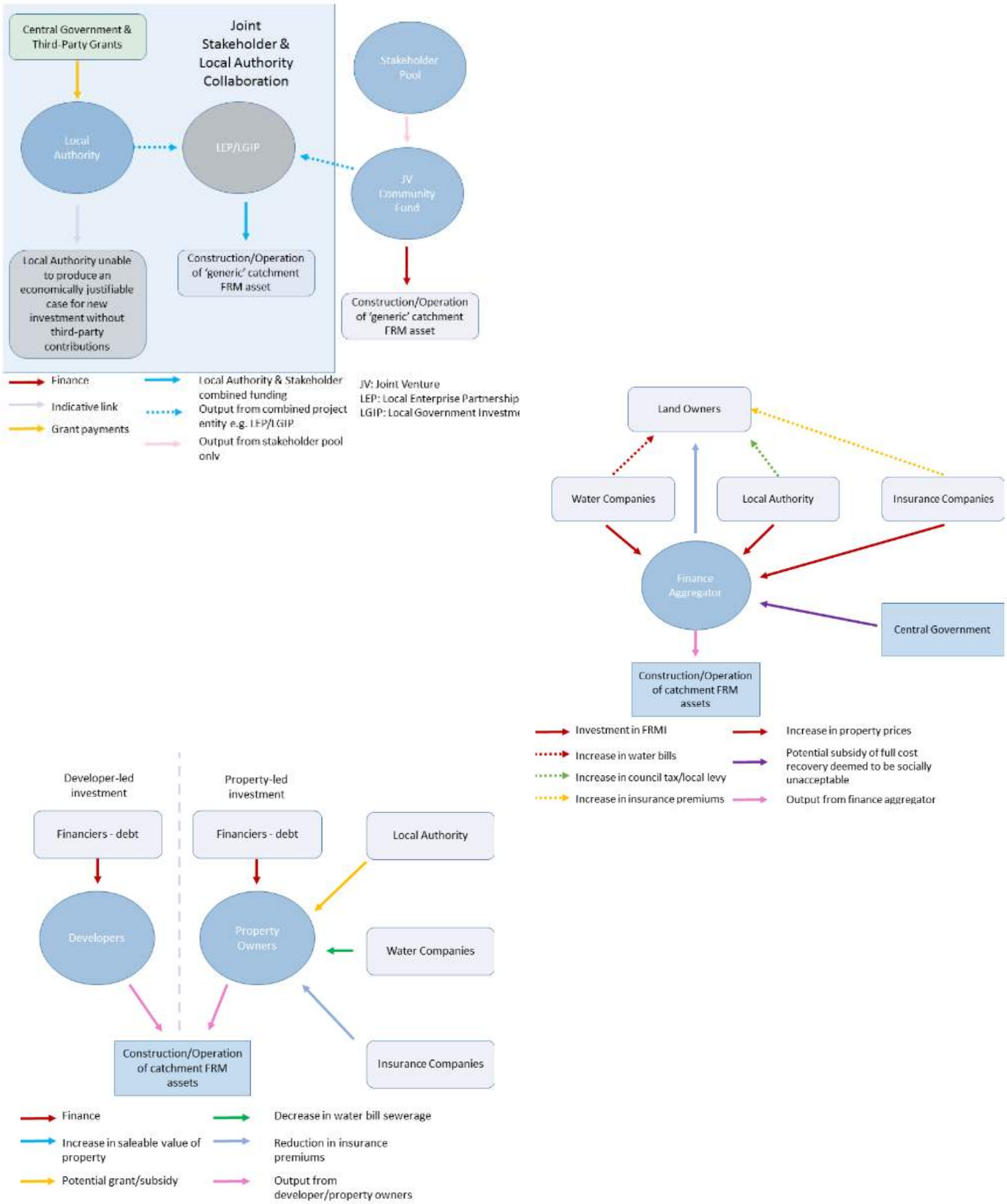


Figure 41 Stakeholder Delivery Business Model (top); cost recovery business mechanism (middle); Development/property owner investment (bottom)[37]

[37] Walsh et al. (2016), *Alternative business models for flood risk management infrastructure* [online] accessed at: https://www.e3s-conferences.org/articles/e3sconf/abs/2016/02/e3sconf_flood2016_20015/e3sconf_flood2016_20015.html

6.5 Next steps

- A carbon assessment appropriate to the level of design will be completed to support Environment Agency assurance of the Strategy.
- Work with funding specialists to develop a detailed funding strategy including identification of funding mechanisms and approach to resolving any shortfall.
- Development of suitable planning instrument(s) supporting the implementation of the Strategy.
- Numerical modelling recommendations including;
    - Update of climate change allowances to reflect changes in guidance.
    - Modelling updates including ground level LiDAR data, representation of flow pathways between flood sub-cells during high magnitude flood events[38].
    - Improvements to the representation of Pill, Shirehampton and Sea Mills either through refining the Strategy model in these areas and/or drawing on the nearby Avonmouth Severnside scheme estuary model.
    - Improvements to modelling to finalise works to ensure no adverse impact upstream of the A4174 (either through refining the Strategy model in these areas and/or drawing on the Bath to Bristol model), works adjacent to the Malago (incorporating the recent housing estate ground levels into the model).
- Additional refinement of the defence designs and alignments will be required when developing an OBC for any of the phases that follow on from the Strategy, including engagement and consultation, and integration of regeneration and placemaking opportunities. This will lead to a refinement of scheme costs and benefits.
- Further consideration to maintenance aspects including assessment on a site by site basis.
- Further consideration of environmental mitigation and net gain enhancement such as landscaping, public realm and habitat improvements .
- Environmental scoping and consenting – i.e. EIA, HRA, WFD. Additional work on defence encroachment areas and numerical modelling to establish the impacts of the scheme on low and high tide levels within the study area. This will be used to ascertain the scale of potential impacts to habitats and areas of loss to inform the requirements for compensatory habitat.
- Further investigate opportunities and enhancements in relation to the Strategy with regards to heritage, environmental and cultural outcomes, interfaces with the Harbour asset management, and areas of growth and regeneration.

[38] The sub-cells within the city centre are separate during smaller magnitude events, however, for large return period events the cells appear to merge in various locations.

Glossary

ABCR	Average Benefit Cost Ratio - the ratio of project benefits to costs over the lifetime of the project, with all benefits and costs discounted to the present day
AEP	Annual Exceedance Probability is the probability associated with a return period, or chance of occurrence in any given year. An event of return period 50 years has an AEP of 1 in 50 or (2%). • *High risk* means that each year this area has a chance of flooding of greater than 3.3%. • ***Medium risk*** means that each year this area has a chance of flooding of between 1% and 3.3%. • ***Low risk*** means that each year this area has a chance of flooding of between 0.1% and 1%. • ***Very low risk*** means that each year this area has a chance of flooding of less than 0.1%.
BCC	Bristol City Council
BAFS "The Strategy"	Bristol Avon Flood Strategy completed in 2020 focusing on managing the risk of flooding from the River Avon to Bristol and neighbouring communities.
BTQ	Bristol Temple Quarter – the area around Temple Quarter and St Philip's Marsh
CAFRA	Central Area Flood Risk Assessment completed 2010 to assess flood risk in central Bristol from the River Avon and its tributaries.
EA	Environment Agency
EIA	Environmental Impact Assessment
FBC	Full Business Case recording the procurement phase, to identify the option that offers the best public value, records the contractual arrangements, confirms affordability and puts in place the agreed management arrangements for the delivery, monitoring and post-evaluation of the project. Document for submittal to Environment Agency to secure GiA funding of a scheme.
FCERM-AG	Flood and Coastal Erosion Risk Management Appraisal Guidance
Flood defence	Structures built to reduce flood risk
Flood risk	A combination of the chance and the impact of flooding in an area. Could be caused by high tides and storm surges, high river levels, heavy rainfall, sewers and drainage overflowing or high groundwater.
Fluvial flood	Flooding caused when excessive rainfall across the upstream catchment causes flows to exceedthe river's capacity.
GiA	Grant in Aid
HRA	Habitat Regulations Assessment
IBCR	Incremental Benefit Cost Ratio, the marginal benefit-cost ratio of one scheme compared to a less costly one, used as a test of whether the additional benefits justify the additional costs.
LPRG	The Environment Agency's assurance Large Project Review Group.
NPPF	National Planning Policy Framework
OBC	Outline Business Case identifying the investment option which optimises Value for Money, prepare the scheme for procurement and put in place the necessary funding and management arrangements for the successful delivery. secure in-principle GiA

PLP or PFR	Property Level Protection or Property Flood Resilience measures applied to individual properties to provide flood proofing
SEA	Strategic Environmental Assessment
SOC	Strategic Outline Case to establish the case for change and to provide a preferred way forward
SoP	Standard of Protection, the return period up to which a flood defence is designed to be effective and beyond which the flood defence will be overtopped/exceeded.
Storm surge	When storms create a surge of higher water levels out at sea that can travel inland, increasing the water level in the River Avon.
Tidal flood	A flood caused by a high tide and/or a storm surge.
WFD	Water Framework Directive
1 in 200 (0.5% AEP)	An event that would have a 1 in 200 chance or 0.5% probability of occurring in any given year.
2017 study	Study completed in 2017 appraising options to manage the risk of tidal flooding.

ARUP

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Key supporting documents

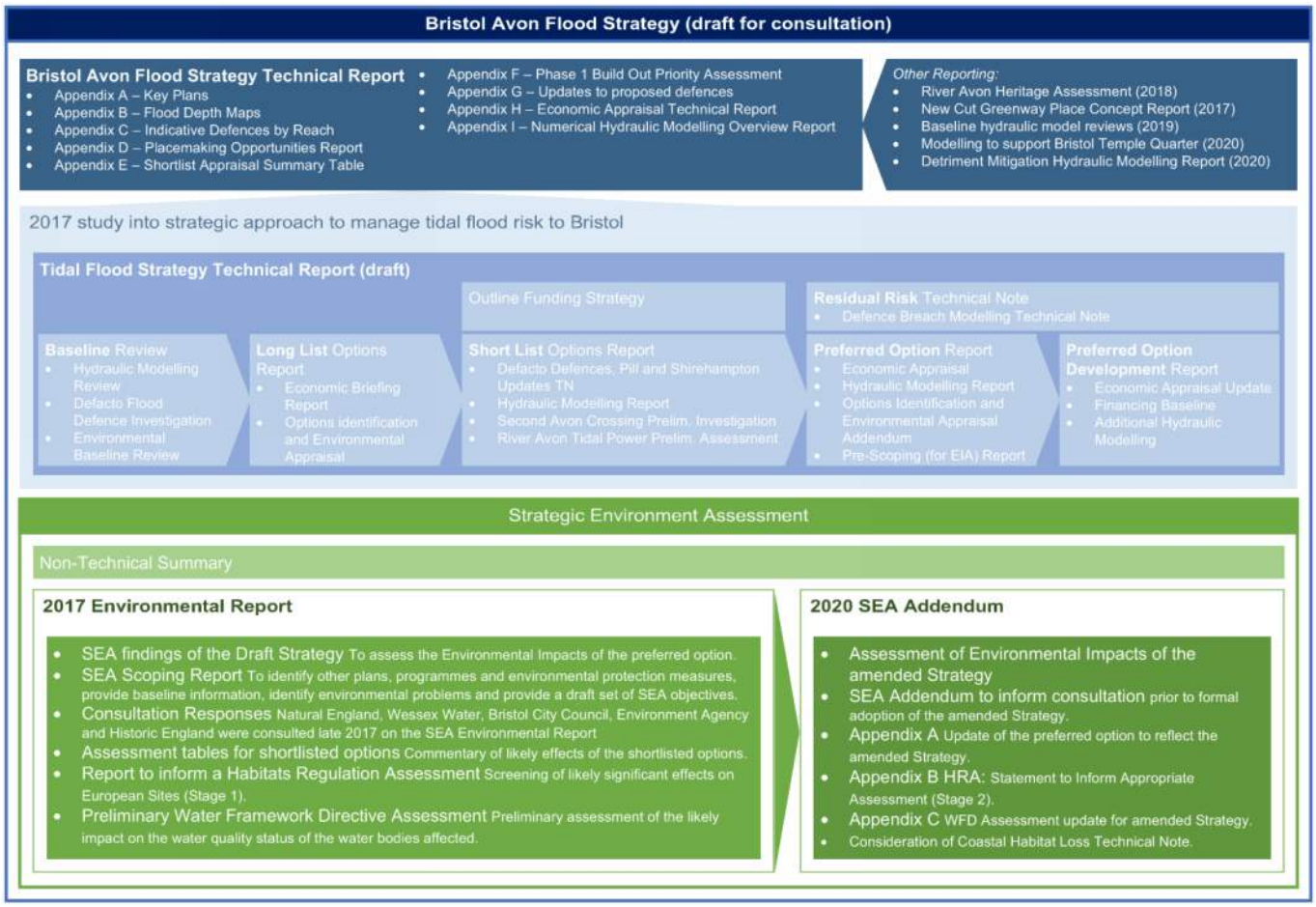
Non-Strategy key documents

Severn Estuary Shoreline Management Plan (2010, Environment Agency)

Bristol Avon Catchment Flood Management Plan (2012, Environment Agency)

Bristol Central Area Flood Risk Assessment (CAFRA) (2010, Bristol City Council)

Strategy reporting summary



Appendix A

Key plans

Appendix B

Flood depth maps

Appendix C

Proposed defences

Appendix D

Placemaking opportunities report

Appendix E

Shortlist appraisal table

Appendix F

Priority assessment Phase 1 build out

Appendix G

Defence options report

Appendix H

Economic assessment report

Appendix I

Flood modelling overview report