River Avon Tidal Flood Risk Management Strategy

Strategy Technical Report

November 2017

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1. EXECUTIVE SUMMARY

1.1 Introduction

Bristol is a thriving city and important to the success of the South West, however the city centre is at growing risk from tidal flooding. The River Avon Tidal Flood Risk Management Strategy sets out a strategic plan for managing tidal flood risk to Bristol. The ambition is to provide infrastructure to manage the tidal flood risk whilst integrating transport and land use opportunities to maximise the city's economic success, resilience, health, social opportunity and quality of life.

This Strategy has been developed by Bristol City Council (BCC), with support from the Environment Agency and consultants AECOM.

The Strategy covers the River Avon between the M5 road bridge (downstream boundary) and Netham (upstream boundary). A map showing the study site is shown in Key Plan 1. This report is presented in the structure of a Strategic Outline Case (SOC) in line with Defra's five case business model.

1.2 Strategy Objectives

Several key objectives were defined for the Strategy. These were integral to the option appraisal processes and are to be used as critical success factors to assess and monitor performance of the Strategy's outcomes:

- To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks;
- To facilitate sustainable growth of Bristol and the wider West of England economy by supporting development opportunities for employment and residential land, and associated infrastructure;
- To maintain, and where possible enhance, natural, historic, visual and built environments;
- To ensure navigation of the River Avon and marine activities can continue; and
- Ensuring that the Strategy is technically feasible and deliverable over its duration.

1.3 Strategic Case

Tidal flooding represents the most significant risk for Bristol's City Centre with the potential for severe consequences. Today there is a 1 in 200 (0.5%) annual chance of tidal flooding to 488 homes and 486 businesses. If no action is taken by the end of the century, some 2,340 homes, 1,350 businesses and most of the city centre will be at risk due to sea level rise.

Table 1. Properties at risk of flooding in Bristol over the next 100 years in the absence of Strategic Flood Risk Management.

Return period	Year	Residential properties at risk of tidal flooding	Commercial properties at risk of tidal flooding	Total properties at risk of tidal flooding
0.5% chance of occurrence (1 in 200 year event)	2015	488	486	974
	2030	579	497	1076
	2065	1673	964	2637
	2115	2342	1347	3689

The Strategy preferred option is in line with the Shoreline Management Plan (SMP) ‘hold the line’ policy and the Catchment Flood Management Plan (CFMP) policy which is to ‘take further action to reduce flood risk to ensure that the standard of protection through Bristol is improved where required’.

The main benefit will be resilience and avoiding losses - a substantial reduction in current and future flood risk, protecting people, properties, businesses, infrastructure and heritage assets. The project safeguards the Enterprise Zone and wider city centre which is of strategic importance to the South West.

Figure 1 – visualisation of 1 in 200 chance event if no action is taken by 2110 (credit – BCC/Arup)

The majority of properties at risk of tidal flooding are located within the city centre. Low spots along the banks of the River Avon and the walls of the Floating Harbour are the first pathways for tidal flood water to inundate parts of the city centre. Flooding currently poses a threat to lives, property and the long term economic prosperity of the city. Should a tidal flood event occur there would be a lasting widespread impact with hazardous flood water, damage to property, damage and disruption to infrastructure, and loss of cultural heritage.

BCC operates tidal gates and other 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 and some key assets are approaching the end of their life. In addition, operation of the Floating Harbour depends on safe access to the operational locations which could be restricted during times of flooding. This makes the continued operation of this key part of the flood risk management system increasingly untenable over time, especially with predicted climate change further exacerbating the pressure on an ageing system. Without significant investment and upgrades there is a high risk of far reaching, regular and significant tidal inundation to the heart of Bristol.

There have been many recent near-misses such as tidal events in 2014 when flooding closed roads including the A4 Portway, Cattlemarket Road and Cumberland Road. The proactive use of a temporary barrier protected properties from flooding as they had in 1981.

Currently developments proceed in the city centre reliant on threshold raising above 1:200yr (0.5% AEP) tidal levels (including climate change), and reliance on emergency plans. However there are two issues:

- The tidal strategy has highlighted the funnelling of tidal events in the city which logically could lead to concern over flood plain storage loss in addition to local adjacent impacts from land raising within the flood plain. The Environment Agency historically views this as a tidal ‘level’ problem however as the evidence base expands there is a risk that this may change.

- Planning practice guidance states “Access considerations should include the voluntary and free movement of people during a ‘design flood’, as well as the potential for evacuation before a more extreme flood.”

Therefore flood risk is currently a threat to existing property and a constraint on the scale and form of 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 development in the central area.

Once implemented, the strategy will provide the nationally prescribed standard of protection required for new development to proceed. It will still be necessary for future development to acknowledge the residual flood risk and the threat posed by residual flooding will be afforded by the provision of site specific mitigation/evacuation measures.

The Strategy will address tidal flood risk, the dominant source of flooding in Bristol. It will also reduce risk posed by high fluvial flows from upstream in River Avon, although further assessment of this is planned. The Strategy's main benefit will be increased resilience of the city due to a substantial reduction in current and future flood risk, protecting people, properties, businesses, infrastructure and heritage assets. The Strategy will safeguard the Enterprise Zone and wider city centre which is of strategic importance to, and an economic driver of, the South West.

Secondary benefits will include reducing the constraining effect of future flood predictions on the scale and form of future development, and opportunities to integrate new defences within wider regeneration. Key delivery risks of the Strategy revolve around certainty of funding, a need for consents and approvals, interfaces with existing assets with limited information, and satisfying stakeholder requirements.

The pressing need to provide flood defences along the River Avon has been identified as creating the opportunity to carry out transport and public realm improvements. The 'New Cut Greenway' could reshape, repair and reconnect the city to the river, promote foot and bike travel, improve safety, make accessible places and maximise development potential. It would ensure the flood investment also delivers essential transport and housing outcomes for the city and wider region. Other cities divided by rivers have successfully seized similar opportunities and used them to regenerate more disadvantaged areas such as Belfast, Derby, Dublin, Glasgow and Sheffield. Further scoping and option development is planned, subject to funding, in advance of finalising the SOC.

1.4 Economic Case

The strategy will deliver an estimated £1.6 billion in benefits to the UK by reducing flood risk over the next 100 years. The benefit to the local economy could be over 2.5 times this value.

The Floating Harbour and its continued operation reduces present-day tidal risk (£1.3bn benefit in today's prices), but its resilience and effectiveness reduces significantly due to sea level rise.

In development of the Strategy a range of options were appraised to determine the preferred strategic option to manage tidal flood risk over the next 100 years. The process started with identification of a long list of potentially feasible options. A list of 39 options was reduced to a short list of seven through multi-criteria analysis, and then to a single preferred option. Throughout this process consideration was given to the achievement of key objectives: reduction in flood risk, cost, economic efficiency, technical feasibility, maintenance of navigation, environmental impact and ability of the option to help sustain development and growth in Bristol.

During the short listing and preferred option selection process, a tidal flood barrier across the Avon was considered but rejected. This was principally on grounds of the potential for adverse environmental impact and because new linear flood walls would deliver greater flood reduction benefits at a much lower cost. Potential for wider benefits to be incorporated into a barrier solution (e.g. transport link) were considered but this failed to sufficiently improve the economic case for a tidal barrier.

The case for improved defences to protect Pill and Shirehampton can be considered separately, and the Strategy was refined to focus on the City Centre.

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.

The preferred option involves constructing 6.2km of flood defences; delivered in phases (see Key Plan 2).

- **Phase 1** works to protect the Floating Harbour from surge with flood walls for critical locations where defences are lowest along the New Cut and new gates at Entrance Lock and Netham. There is a strong case for the works to be completed as soon as possible. The Strategy baseline is 2015 however the process of design development and consenting delays the likely earliest opportunity for construction until between 2023 and 2025. Localised works to existing defences at Bower Ashton, upstream of Netham and opposite Totterdown on the south bank and Property Level Protection (PLP) at Bedminster. These elements are needed as the defences elsewhere would raise water levels in the New Cut, which if not mitigated would lead to increased risk of flooding in these locations.

- **Phase 2** consists of further walls along the New Cut in 2030s.
- **Phase 3** defences works to heighten when necessary due to sea level rise (notionally 2065 but capable of being brought forward or delayed according to the pace of sea level rise) to ensure an adequate standard of protection through to 2115

Phase 1 and 2 typically comprise walls 0.7-1.1m high, providing a notional standard of 1 in 200 chance (0.5% AEP) 2030, but an effective 1 in 200 chance standard through to 2065 (with freeboard considered). The defences planned for these initial phases are referred to as 'low' defences in the Strategy.

Works planned for 2065 will raise defence heights through the City to a typical 1.4-1.8m. The upper part of defences could be formed in glass or alternative landscaping measures adopted to minimise visual impact and where possible enhance the public realm. The raised defences planned from 2065 are referred to as 'high' defences in the Strategy.

The environmental assessment work undertaken to support option appraisal, including development of an SEA, shows that the strategy will deliver significant positive impacts for population, health and material asset receptors through reducing flood risk. Potential negative impacts have been identified for receptors such as biodiversity and cultural heritage; however with appropriate mitigation and compensation these adverse impacts can be avoided or minimised so that the Strategy implementation remains environmentally sustainable. Further, subsequent detailed studies, will be required to assess impacts in terms of the Habitats Regulations and Water Framework Directive and identify suitable mitigation measures. The present value cost of the option is estimated at £67m, with the option having an average benefit cost ratio of 23:1.

Summary of Key Benefits of the Strategy:

Future Proofing - nearly 3700 properties better protected against flood risk in Central Bristol over the next 100 years.

Adaptive – mitigates climate change and sea level rise with sufficient flexibility to adapt to the range of future scenarios and thereby maximising return on investment.

Catalyst - supports economic prosperity and Bristol's development and regeneration aspirations.

Broader Outcomes - potential to deliver public realm and access improvement through linkage and delivery of New Cut Greenway plans.

Environment – the delivery of the strategy provides opportunities for environmental enhancement (e.g. native planting, urban greening etc.)

1.5 Commercial Case

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

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:

- Water and Environment Management Framework (WEM framework)
- Scape Procure – Civil Engineering and Infrastructure Framework (Scape Framework)
- BCC Flood risk consultancy framework
- Bespoke tender

1.6 Financial Case

The total undiscounted cost of the Strategy is estimated at £125 million over the next 100 years. The discounted cost is approximately £67m. The breakdown of undiscounted and discounted costs across the three epochs is show in Table 2 below. These figures include maintenance and operation costs for the Floating Harbour and 60% optimism bias.

Table 2. Strategy implementation, costs and funding.

Phase		**Flood defence capital costs (£m undiscounted) based on outline design including 60% optimism bias**			**Present value (£m discounted)**		
		Cost (design and construction)	**Funding gap**	**Funding commentary**	**OPEX**	**Gate OPEX**	**Total**
Phase 1 2019-2025	Walls typically 0.7-1.1m & gates to prevent surge entering harbour	43.3	0	*EA FDGiA £34.7M-£43.3M** *LEP Economic Development Fund (EDF) £5M (allocation 2023).*	0.5	0.4	**44**
Phase 2 2030-40	Walls along New Cut	18.4	11	*EA FDGiA £2.5M* *LEP EDF £5M (prog. allocation 2032).* *Other potential sources: WECA programme, CIL, BID, private development cash/in-kind contributions.*	2.0	0.6	**13**
Phase 3 2060-70	Raise all defences ~0.7m	44.2		N/A	0.7	0.5	**10**

**subject to which baseline is adopted in partnership funding calculator*

Flood and Coastal Erosion Risk Management Grant in Aid (FCERM GiA) eligibility depends on a partnership funding formula. The case for GiA for phase 1 is strong with a maximum partnership funding score of 135%. Based on this the potential FCERM GiA funding amount for the phase 1 scheme is up to approximately £43m. However as part of this phase of work various key parameters and assumptions have been sensitivity tested and this has demonstrated that there remains a degree of uncertainty in the PF score baseline and a potential £9m funding shortfall could result (see Financing Baseline technical note). Therefore confirmation of the partnership funding arrangements for the phase 1 works is required and further dialogue with the EA's Large Project Review Group (LPRG) is recommended at the earliest opportunity.

The case for GiA for phase 2 is less strong. The partnership funding assessment for the phase 2 scheme has been based on the benefits against the Do Nothing scenario as the baseline, reflecting the low operational resilience and high vulnerability of the Floating Harbour. New Cut Greenway costs would not be eligible for GiA but would deliver considerable wider benefits to the area.

It should be noted that FCERM GiA does not cover maintenance and operational costs. 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.

In the course of Strategy development, a number of other funding sources have been identified. The Local Enterprise Partnership's Economic Development Fund has a programme allocation of £5m (2023) and £5m (2032). Other potential identified flood defence 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 Strategy assumes the continued maintenance of existing Floating Harbour and New Cut retaining walls. In general, the Strategy is dependent on the continued serviceability of some of these structures.

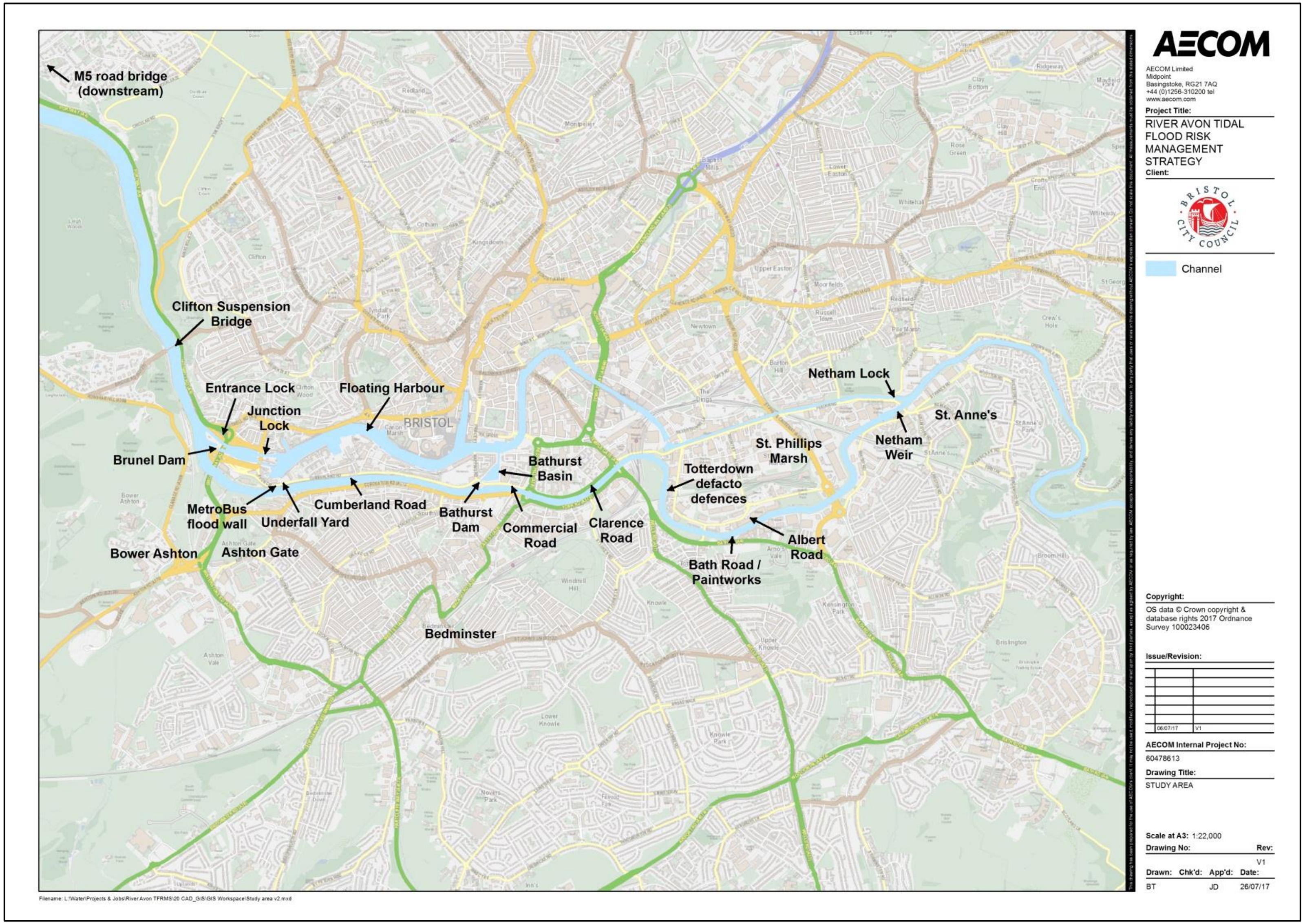
1.7 Management Case

The OBCs and detailed design / scheme construction projects will be overseen by a multi-agency Project Board comprising senior management representation from BCC, the Environment Agency and the appointed supplier(s) and will be supported by a project team led by a dedicated Project Manager.

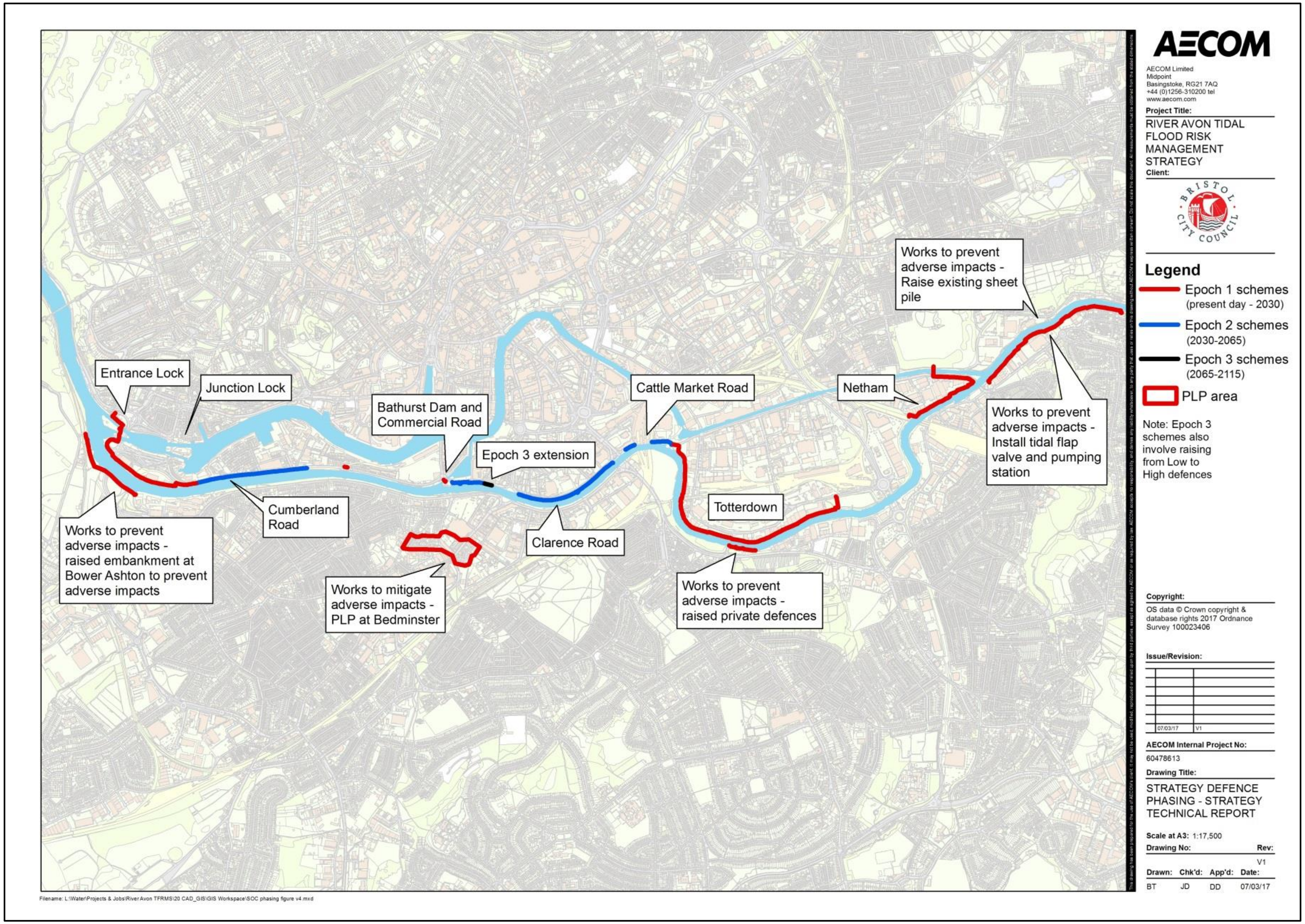
The Strategy will be delivered using powers under the Flood and Water Management Act or Water Resources Act. BCC is the landowner for the majority of the Strategy however in St Phillips, east of Temple Meads there will be third-party interfaces.

The next steps for the Strategy and further work prior to design and construction of Phase 1 works include:

- Additional refinement of the defence designs and alignments will be required when developing an OBC for any of the schemes that follow on from the Strategy.
- Liaison with LPRG to verify the baseline assumptions used to assess outcome measures in the Partnership Funding calculations and to confirm the level of Grant in Aid funding which may be available.
- Further consideration to maintenance aspects including assessment on a site by site basis.
- Further consideration of environmental mitigation measures such as landscaping, public realm improvements and compensatory habitat provision for the potential loss of intertidal habitat.
- Development of the New Cut Greenway proposals.
- 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.
- More detailed numerical modelling to investigate flow pathways between flood cells during high magnitude flood events.
- Additional numerical modelling to help quantify fluvial benefits of the Strategy (note that fluvial benefits have not yet been included in the benefits of the Strategy).
- Interface with wider opportunities and programmes, including the Harbour Asset Management Strategy.



Key Plan 1: Bristol City Centre



Key Plan 2: Strategy implementation plan. Phase 1 Schemes – Red (epoch 1), Phase 2 schemes – blue (epoch 2) and Phase 3 schemes – black (epoch 3).

2. THE STRATEGIC CASE

2.1 Introduction

2.1.1 *Background*

The River Avon Tidal Flood Risk Management Strategy sets out a strategic plan for managing tidal flood risk in central Bristol, Pill and Shirehampton. The Strategy has been developed by Bristol City Council (BCC), with support from the Environment Agency and consultants AECOM. BCC led 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, civil protection and major landowner roles.

This report is presented in the format of a Strategic Outline Case (SOC). At this stage, the report is primarily intended to inform BCC decision makers rather than be used as a formal SOC submission. More work, such as formal public consultation and engagement with statutory consultees, will be needed to advance the Strategy to a stage suitable for formal submission to the Environment Agency.

During the course of Strategy development, a considerable body of evidence has been produced. Key supporting documents to the Strategy are listed below and in Appendix A.

Key supporting documents:

- Baseline reports; technical, environmental and modelling reviews.
- Option development reports; long list options report and short list options report.
- Supporting option development reports; Environmental options report, economic damages report, option modelling report, SEA report.
- Preferred option report.
- Preferred option refinement deliverables; preferred option development report, preferred option modelling report, outline design report, residual risk report, funding strategy, WFD and HRA.

The area addressed by the Strategy is the area adjacent to the River Avon between the M5 road bridge near Avonmouth (downstream boundary) and Netham (upstream boundary). Flood risk in this area is dominated by tidal events, and the majority of properties at risk of flooding are located within Bristol city centre and the Floating Harbour. Low spots along the banks of the River Avon and the walls of the Floating Harbour are the first pathways for flood water to inundate a significant number of properties in central Bristol.

The Strategy has been developed because effective strategic tidal flood risk management is essential for the long term sustainability of Bristol. Flooding poses a threat to lives and to property and to the long term economic prosperity and viability of the City.

As a consequence of climate change and continued warming of the global oceans, sea levels are expected to increase in the future. This will increase the flood risk in the study area over the next 100 years unless appropriate action is taken. The impact of projected sea level rise (UKCP09 medium emissions scenario 95%tile) on a range of extreme tide levels is presented in Figure 2.

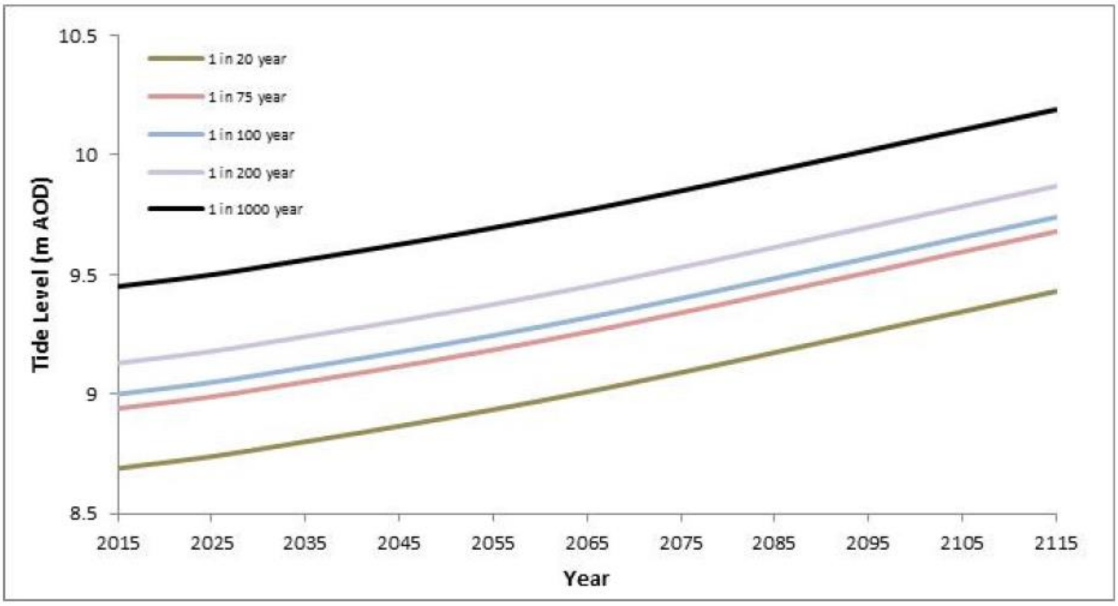


Figure 2. Extreme tide levels and impact of sea level rise for the study (Avonmouth)

A present day 1:200 year flood event (0.5% AEP or a 1 in 200 chance of occurring in any given year) would result in the flooding of around 1000 properties in the Strategy area. If no action is taken, by 2115, due to projected sea level rise, a 1 in 200 (0.5% AEP) event would result in flooding to approximately 3700 properties, and inundate most of the City Centre. In addition, a major flood event which currently has a 0.5% annual change of occurring now, could occur as frequently as every year by the end of the century if no strategic management of the risk is implemented.

Flood risk is currently a threat to existing property and a 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. Once implemented, the strategy will provide the nationally prescribed standard of protection required for new development to proceed. Protection from the potential threat posed by residual flooding will be afforded by the provision of site specific mitigation/evacuation measures.

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 and some key assets are approaching the end of their life.

2.1.2 *Flood risk*

Bristol has a history of flooding. Numerous place names throughout the city centre, such as Temple Meads and St. Phillips Marsh suggest a long history of regular tidal flooding. Recent localised tidal flooding has been recorded in 1981, 1990, 1999 and 2014 at locations such as the Portway, Cumberland Basin, Avon Crescent, Coronation Road and Cattle Market Road. A 1.6m tidal surge in 1981 flooded properties at Avon Crescent and Shirehampton.

There have been many recent near-misses such as tidal events in 2014 when flooding closed roads including the A4 Portway, Cattlemarket Road and Cumberland Road. Good weather reduced forecast surge levels. The proactive use of a temporary barrier protected properties from flooding as they had in 1981.

Figure 3. Photograph showing Cumberland Basin overflowing into the Floating Harbour at Junction Lock, 2014 (phot from the first phase feasibility study)

A ‘Do Minimum’ scenario represents a continuation of the status quo, assuming existing activities (e.g. operation of stop tide gates in the Floating Harbour) are able to be continued and the current defences are kept in place, but not raised. Numerical modelling has shown that under this scenario a present day 1:200 year flood event (0.5% AEP) would result in the flooding of approximately 1000 properties in the strategy area.

Due to sea level rise future flood risk is expected to increase. By 2115, a 1:200 year event (0.5% AEP) would result in flooding to approximately 3700 properties. Figure 4 and Figure 5 show the Do Minimum flood extent for a 1:200 year event in 2015 (0.5% AEP) and 2115 respectively. Further flood risk maps are presented in Appendix B.

Table 3. Properties at risk of flooding over the next 100 years under a Do Minimum scenario

Return period	Year	Residential properties at risk of tidal flooding	Commercial properties at risk of tidal flooding	Total properties at risk of tidal flooding
0.5% chance of occurrence (1 in 200 year)	2015	488	486	974
	2030	579	497	1076
	2065	1673	964	2637
	2115	2342	1347	3689

The main areas of 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.

In addition to the large number of properties that are at risk there are also wider implications of flooding. For example tourist attractions within Bristol are also be at risk, such as the SS Great Britain (located in the Floating Harbour) and access to and from Bristol Temple Meads railway station (a key transport hub for the wider south-west region) would also be affected. Bristol is also a key economy to the south-west region and more frequent/severe flooding in the city is likely to have widespread impacts across the region.

Flooding can also have large social consequences for communities and individuals. 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, risk of 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.

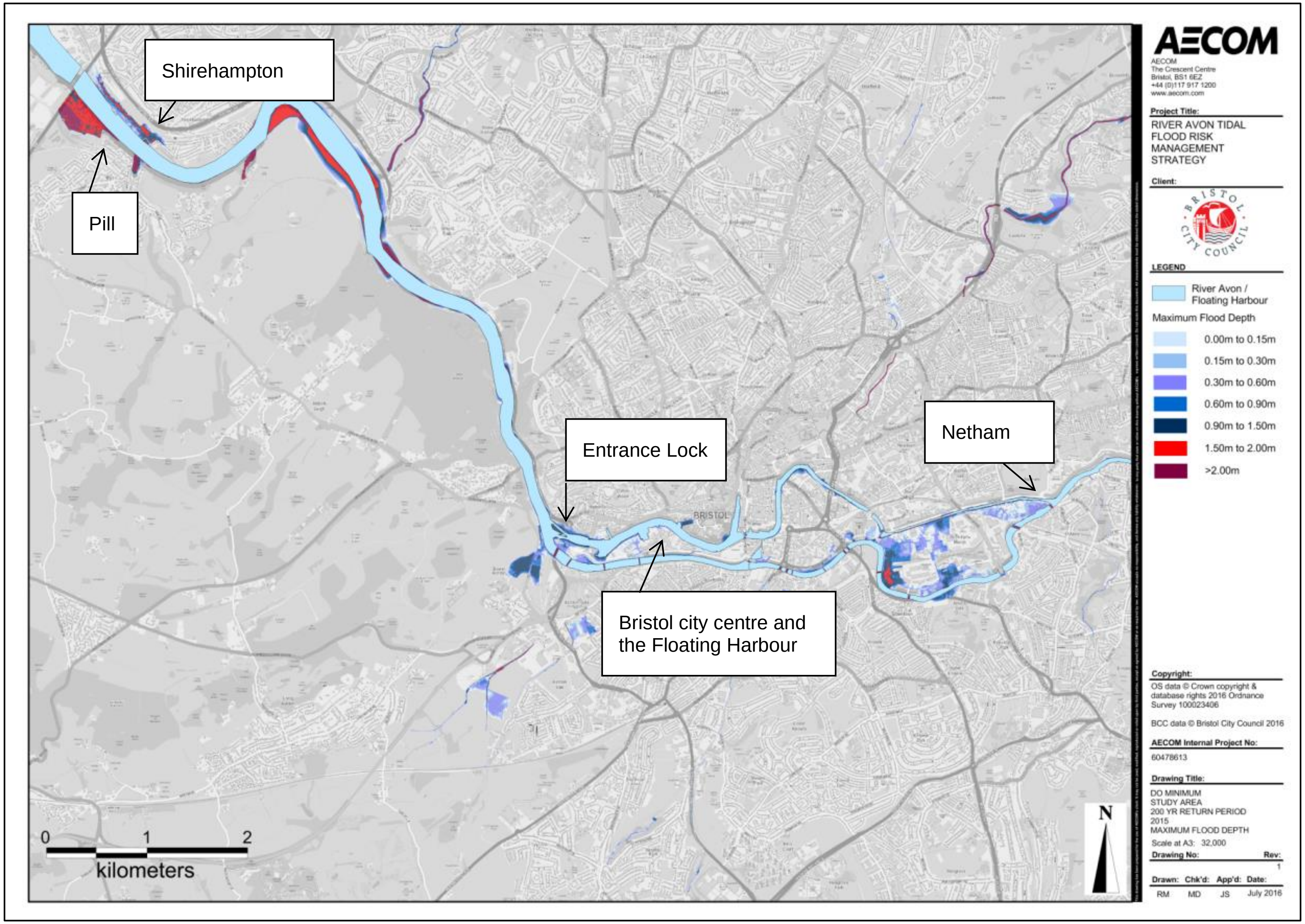


Figure 4. **Flood depths for a 1:200 (0.5% AEP) year event (2015) under the Do Minimum scenario**

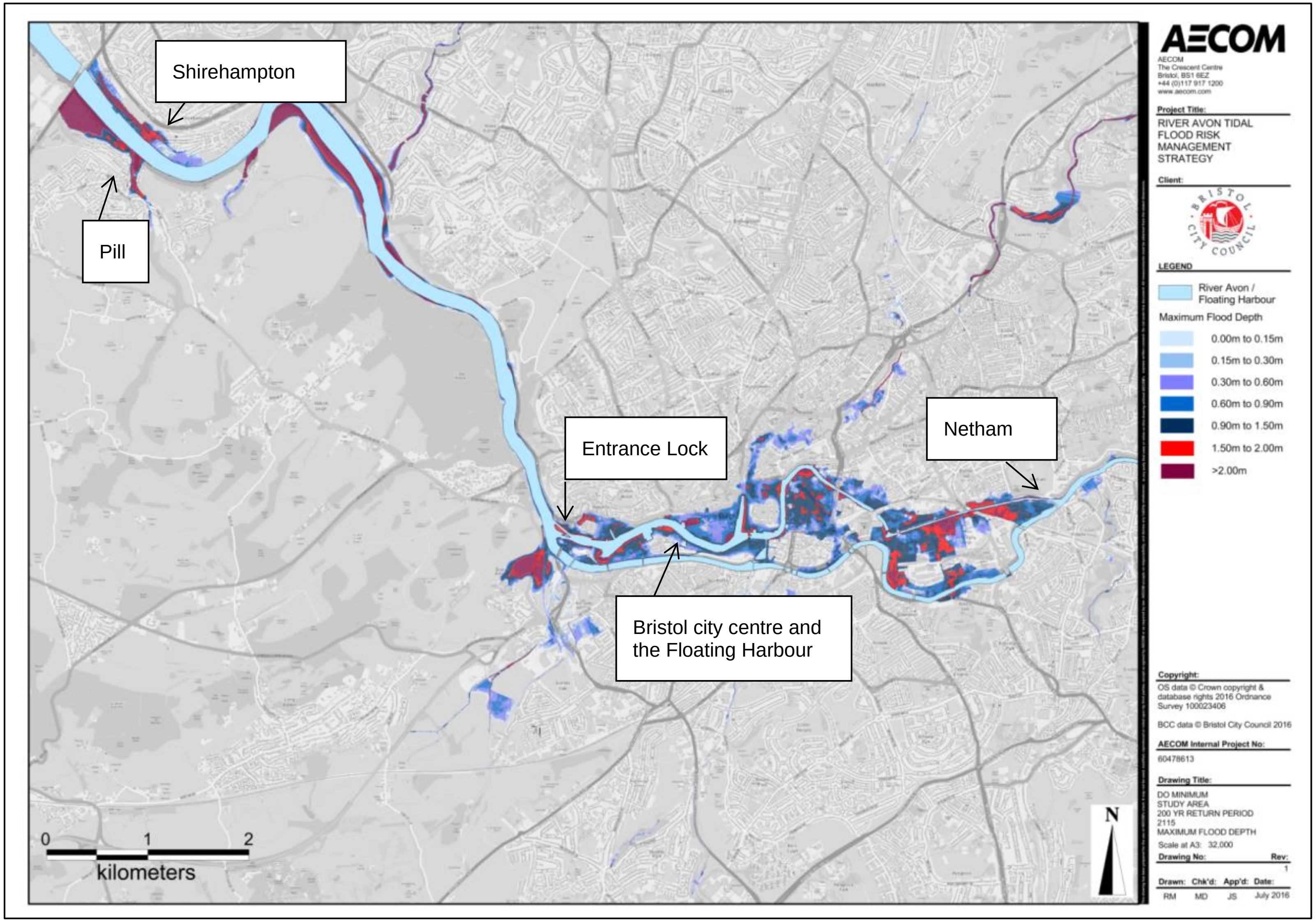


Figure 5. **Flood depths for a 1:200 (0.5% AEP) year flood event (2115) under the Do Minimum scenario**

2.2 Business Strategies / Planning Frameworks

2.2.1 *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 Environment Agency’s FCERM Wessex Strategy also 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 and 2015.

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, the Severn Estuary Flood Risk Management Strategy is currently being drafted. The Strategy will define 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 Defra or the Welsh government and is considered a working draft at this stage.

2.2.2 *Planning Policy*

National Planning Policy Framework (NPPF) 2012, sets out the Government’s planning policies for England. The Bristol Local Plan (running to 2026) and Core Strategy (2011) set out the development objectives for Bristol. The plans include the council’s approach to minimising the risk and impact of flooding in the context of new development and the spatial strategy is based on a sequential approach whereby priority is given to development of sites with the lowest risk of flooding.

Within the city centre the areas of focus for development and regeneration include Harbourside, Redcliffe and Broadmead. Development within the Bristol Temple Quarter Enterprise Zone is intended to attract more than 17,000 jobs to the area over the next 20 years.

By identifying the level of tidal flood risk across the city the Strategy helps to support implementation of planning policy. The Strategy will inform the upcoming review of the Local Plan.

By providing a robust route map to deliver higher standards of flood protection, the Strategy will reduce future constraints (location, type and physical form) on development caused by flood risk and create opportunities for sustainable development (subject to development ensuring suitable mitigation strategies to address residual risks).

2.3 Environment and other considerations

2.3.1 *Environmental studies*

A number of environmental studies have been undertaken throughout the development of the Strategy which have fed into the option appraisal process at key stages. Integral to the development of the preferred strategy approach was the production of a Strategic Environmental Assessment (SEA). The SEA comprehensively assessed the proposed flood management approach and evaluated the environmental impacts of different options.

The SEA process, coupled with a multivariate 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.

Further studies such as a preliminary Water Framework Directive Assessment (WFD) and Habitats Regulations Assessment (HRA) Screening has also been undertaken. In future studies it will be necessary to complete these assessments to support the implementation of the Strategy schemes. Schemes will also be subject to the full planning approval process so ensuring environmental compliance will be essential.

2.3.2 *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 the Avon Gorge Site of Special Scientific Interest (SSSI), the Avon Gorge Special Area of Conservation (SAC), the Horseshoe Bend SSSI, Ashton Court SSSI, Ham Green SSSI and 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). For maps of the environmental designations within and adjacent to the study site refer to the various environmental assessment reports.

2.3.3 *Cultural heritage*

There are a number of features important to the cultural heritage of the area within the study site. These include numerous scheduled monuments such as Underfall Yard (within Bristol Docks). There are several Grade I, Grade II and Grade II* listed buildings within the study site, including the Clifton Suspension Bridge (Grade I). Many of the listed buildings are located in close proximity to the River Avon channel or the Floating Harbour and are particularly sensitive to flooding. There are a number of registered parks and gardens, MShed, and the popular tourism asset of ss Great Britain also at risk of flooding.

2.3.4 *Others sources of flooding*

Whilst tidal flooding is the key source of risk being addressed by the strategy there is also a significant fluvial flood risk from the River Avon, the River Frome and other tributaries. The fluvial flood risk has been considered and there are also clear fluvial flood risk benefits from implementing the Strategy. The extent of tidal dominance in the New Cut channel changes depending on tide conditions. Under extreme conditions the tide can extend upstream of Netham Weir.

Other sources of flooding, such as surface water 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 detrimental impacts suitably mitigated in the design and delivery of required schemes.

2.4 Investment 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. The objectives are:

- To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks.
- To facilitate sustainable growth of Bristol and the wider West of England economy by supporting development opportunities for employment and residential land, and associated infrastructure.
- To maintain, and where possible enhance, natural, historic, visual and built environments.
- To ensure navigation of the River Avon and marine activities can continue.
- To ensure that the Strategy is technically feasible and deliverable over its duration.

2.5 Current arrangements

2.5.1 *Flood defences / infrastructure*

Bristol City Centre

Numerical model simulations show that tidal 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.

The primary aim of existing infrastructure and operating procedures is to reduce the volume of water which flows into the Floating Harbour because once the storage capacity is exceeded it leads to the greatest amount of flooding in the city. Stop gates are deployed at Junction Lock (the downstream entry point to the harbour) to stop water from flowing directly from the River Avon channel into the harbour (Figure 3) and the lock gates at Netham (upstream entry point to the harbour) are also closed to prevent water entering at this entrance (Figure 6).

At Junction Lock the land levels adjacent to the Stop gates are actually lower than the gates crest level and when the gates are closed, if water levels are high enough, the flood water can enter the harbour by flowing over the adjacent land. Other low points in the defences adjacent to the harbour also serve as entry points, such as Bathurst Basin Dam.

In addition to the above, water levels in the Floating Harbour are lowered up to 0.5m prior to a flood event to increase the storage capacity of the harbour and reduce the likelihood of flooding in central areas should water enter the harbour. Water level control infrastructure is used to pre-lower the harbour, including the sluice system at Underfall Yard.

Figure 6. **Lock gates at Netham (open position, looking upstream to the north-east)**

Along the banks of the New Cut the retaining walls form the primary defence against flooding. However, there are a number of low spots and the condition of the retaining walls is poor in places and deteriorating. The locations along the New Cut where there are low points and properties are at risk are 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. Phillips / Totterdown. The MetroBus flood wall (Figure 7) is constructed to a present day 1:100 year standard (1% AEP) but the St. Phillips / Totterdown defences are of a much lower standard. During recent flood events temporary barriers have been deployed in the most vulnerable areas. For example, in 2014 a temporary barrier deployed at Cumberland Road helped prevent flooding to properties.

Figure 7. Newly constructed MetroBus flood wall (Cumberland Road)

The procedures to manage flood risk in central Bristol are currently reliant on effective and timely flood forecasting. This is carried out by the Environment Agency who give sufficient warning to close the Floating Harbour stop gates, pre-lower the harbour and to deploy temporary flood barriers.

Operation of the Floating Harbour is dependent upon human intervention to operate the water level control infrastructure (e.g. closing the lock / stop gates). This could be compromised during times of flooding because safe access to the control infrastructure could be restricted by flood waters or debris. There are currently three main operational locations; Junction Lock, Netham Lock and Underfall Yard. Table 4 presents the typical peak flood hazard rating (combination of flood depth and velocity) for these areas over a variety of return periods (1:2 to 1:200 year return period). As can be seen, 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.

There are limitations and uncertainties associated with analysis of hazard mapping to infer vulnerability of the Floating Harbour system, not least that the operation period should be prior to peak tidal levels (provided there is sufficient warning to close the stop / lock gates). However, the analysis gives an indication of the potential challenges for trained operated to respond to operational issues.

Table 4. Flood hazard rating at Floating Harbour operational locations

		Typical peak hazard rating		
Epoch	**Flood return period**	**Netham Lock**	**Junction Lock**	**Underfall Sluice**
2015	2	1.0	0.9	0.6
	20	1.1	1.2	0.6
	75	1.1	1.4	0.6
	200	1.3	1.6	1.2
2030	2	1.0	0.9	0.6
	20	1.1	1.3	0.6
	75	1.1	1.5	0.6
	200	1.3	1.8	1.3
2065	2	1.1	1.1	0.6
	20	1.1	1.5	0.6
	75	1.2	1.8	1.0
	200	1.3	2.0	1.9
2115	2	1.1	1.4	0.8
	20	1.3	1.9	1.3
	75	1.3	2.2	1.9
	200	1.5	2.5	2.5
Key				
<0.75: Very low hazard / Caution				
0.75 – 1.25: Danger for some				
1.25 – 2.0: Danger for most				
>2.0: Danger for all				

Pill and Shirehampton

Pill is located downstream of central Bristol, on the south bank of the River Avon. The frontage is defended by a seawall and a series of manually operated flood gates. With sea level rise the crest level of the seawall will not be sufficient to protect to a high standard of protection in the future.

Shirehampton is located opposite Pill, on the north bank of the River Avon. The frontage includes a mixture of defences and a set of manually operated raised flood gates. The flood gates at Pill and Shirehampton are operated by the Environment Agency and rely on effective and timely flood forecasts.

2.5.2 *Management authorities*

Flood risk in the study area 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 / 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 is 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 river flow and this helps ensure fluvial flood risk is lower than tidal risk.

2.6 Main benefits

The Strategy will deliver a high standard of protection against flooding for Bristol City Centre, Pill and Shirehampton, reducing the flood risk to over 2000 residential and 1300 commercial properties over the next 100 years. This will reduce the economic damages associated with tidal flooding for the next 100 years, as well as providing benefits to the local community, environment and transport infrastructure.

The Strategy will also help to reduce constraints on development in areas which are currently and/or projected to be at risk of flooding in the study area. For example by providing a higher standard of protection against flooding the ground floor levels of development may not be need to be raised as high and therefore development may be enabled by being simpler and less costly.

More details on the economic and wider benefits of the Strategy are presented in Chapter 3; the Economic Case.

Table 5. Main benefits of the Strategy

Key Benefits
- Higher standard of protection against flooding - Reduced flood risk to >2000 residential and >1300 commercial properties - Benefits to local communities, environment and transport infrastructure through reduced flood risk - Reduced constraints on development

2.7 Main risks

The key risks associated with the Strategy have been identified and are presented in **Table 6**. Mitigation measures are also highlighted with the likelihood of the risk occurring after mitigation.

Table 6. Key risks for the delivery of the Strategy

Key risk	Description	Potential impact on delivery – cost and programme	Mitigation	Likelihood - after mitigation
Stakeholder / public / environmental objection to the proposed Strategy	Objections to aspects of the proposals. Impact to designated sites and environmental compliance.	Med	Early consultation carried out during Strategy development – i.e. planning workshops. Seek to continue with consultation during scheme implementation. Strategy approach is adaptive to minimise initial impact on the environment (i.e. visual impact). Environmental studies carried out - Strategic Environmental Assessment (SEA), Habitat Regulations Assessment (HRA), Screening and preliminary Water Framework Directive Assessment (WFD) in Strategy but Environmental Impact Assessment (EIA), full HRA and WFD	Low

Key risk	Description	Potential impact on delivery – cost and programme	Mitigation	Likelihood - after mitigation
			will be needed for scheme development.	
Insufficient budget allocated	Variability in market and costs for material components of the schemes. Redesign of sections of work due to unforeseen technical issues. Potential for issues associated with existing retaining structures and services / utilities	High	60% optimism bias included. Seek early contractor involvement during scheme development. Strategy costs benchmarked against PCT tool to provide greater cost certainty. More detailed design to be carried out prior to construction to identify issues in more detail, including Ground Investigation works and updated utility surveys.	Low
Possibility for a change in partnership funding arrangements for schemes scheduled for the future	Updates to the guidance could change the likelihood of funding	Med	Produce an Outline Business Case (OBC) for future schemes using latest guidance. Strategy has robust Partnership Funding (PF) score and funding requirement within BCC funding capacity.	Med
Risks associated with operators / landowners and access	Constraints on marine working, impacts on navigation and lack of space for construction. Increase in compensation above expected	High	Liaison with harbour authority and continued engagement throughout the design and construction to minimise disruption. Use of alternative construction methods available, such as working from river channel. Develop planning instrument to trigger consent approach to renewal / redevelopment along the St. Phillips frontage. Undertake extensive landowner engagement throughout planning application process, further design and construction to work with landowners / operators to minimise disruption.	Low
Risks associated with the New Cut Greenway proposals	Increased interface / liaison / costs required to deliver New Cut Greenway and funding uncertainty for additional proposals	High	Early liaison with all involved parties Seek funding opportunities early on. Suitable costs included for basic cladding and like for like reinstatement. To apply suitable allowances during detailed design. Work underway to develop New Cut Greenway concepts.	Med
Risk associated with working with heritage /	Risk to design and potential cost escalation to	Med	Understand the existing assets better though further surveys. Included 60% optimism bias to allow for potential unforeseen issues.	Med

Key risk	Description	Potential impact on delivery – cost and programme	Mitigation	Likelihood - after mitigation
ageing assets.	address.			
Unforeseen construction issues (i.e. ground conditions)	Re-design / increased cost to project to address	High	Investigations during next phase and potential to alter design should issues arise	Med
Risks associated with climate change	Uncertainties surrounding climate change projections and timing of interventions	Med	Timing of strategy phases are flexible and trigger levels have been defined. Latest climate change projection guidance adopted.	Med

2.8 Constraints

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

- the need to minimise disruption to adjacent highway network,
- the need to maintain harbour operation; and
- avoidance of disruption to businesses and the community.

There is also the need to ensure that there is no increase flood risk due to implementation of the strategy either through temporary or permanent works. Potential EDF funding for the Strategy implementation is linked to the Enterprise Zone which runs until 2036.

Some additional constraints include the three year time window for construction to commence after receiving planning permission, ensuring construction techniques and timings do not negatively impact the environment, and constraints associated with tidal working.

2.9 Dependencies

2.9.1 *Existing assets*

The Strategy is dependent upon the dockside and New Cut retaining banks and the ongoing operation of the water level control assets within the Floating Harbour. For example, operation of the culvert systems and sluices will need to continue during flood events to prevent flooding within the harbour area (for example at Netham and 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.

The external dependence on the existing assets and need for continued investment outside of the scope of the Strategy is recognised by BCC. The cost of continuing to operate the assets is not known but BCC is committed to funding this. An asset management Strategy is scheduled to be completed and this will form the basis from which BCC will manage the existing assets.

2.9.2 *Partnership funding*

The new schemes identified in the Strategy are dependent on the provision of partnership funding from FCERM-GiA sources. For the first phase of schemes / works, the funding outlook is strong with partnership funding scores of greater than 100%. However, this is based use of the Do Nothing scenario as the partnership funding baseline and this approach needs to be agreed with the Environment Agency's Large Projects Review Group (LPRG) before funding amounts can be confirmed. In order to progress an application for GiA it will also be necessary for the Strategy and the OBC for the initial scheme to be approved by LPRG.

3. THE ECONOMIC CASE

3.1 Introduction

3.1.1 *Time epochs*

To facilitate the appraisal of strategic options for the 100 year appraisal period (present day to 2115) it was necessary to split the appraisal period into three time epochs:

- Present day (2015*) to 2030 (short term)
- 2030 to 2065 (medium term)
- 2065 to 2115 (long term)

**note that 2015 has been used as the conceptual starting date for the Strategy based upon the availability of modelling and the appraisal time epochs that have been agreed. From herein, reference to 2015 equates to the present day i.e. construction scheduled for 2015 means that construction should commence immediately once the necessary supporting studies have been undertaken.*

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 sea level rise. In addition, the approach has built-in flexibility to address future uncertainty to ensure that the timing of future works is appropriate.

3.1.2 *Stages of the appraisal*

Initially a long list of 39 strategic options was developed, with each option outlining a sequence of measures to be implemented across the appraisal period. Supporting technical studies were then carried out, informing a multi-criteria assessment used to produce an option short list of seven strategic options. The preferred option was selected from this list and tested to make sure it was robust. The preferred option was then refined to arrive at a final Strategy.

Figure 8 presents a flow chart showing the appraisal process and the relevant sections within this chapter.

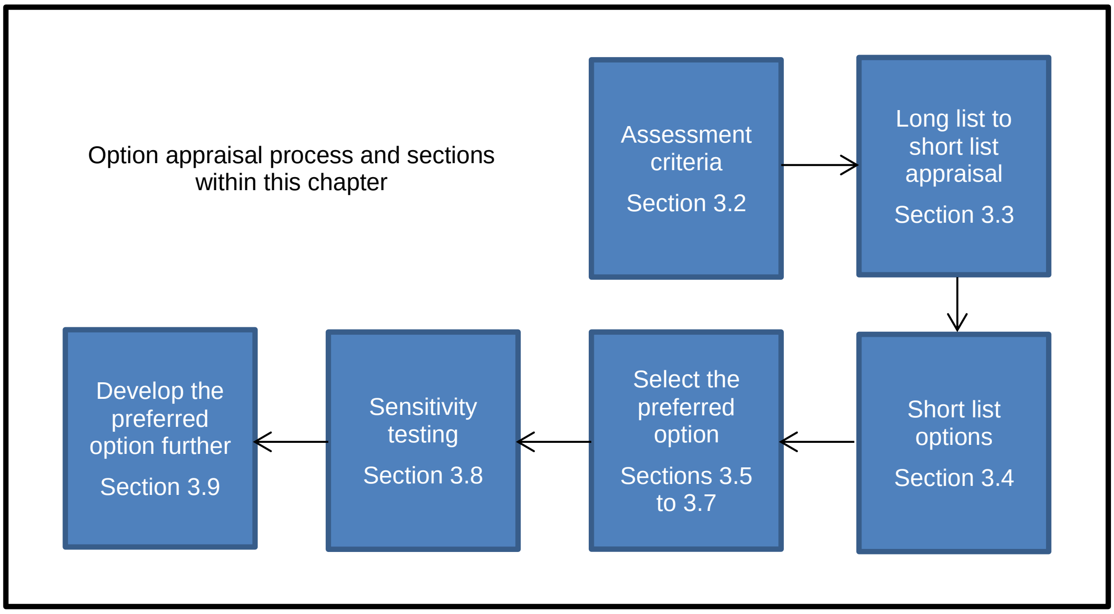


Figure 8. Flow chart showing the option appraisal process and sections within this chapter

3.2 Critical success factors

The critical success factors identified for the Strategy were used to differentiate between the strategic options and formed the basis of the multi-criteria assessment from long list to short list. The critical success factors were focussed around reducing the flood risk for existing communities, whilst acknowledging important wider objectives of the Strategy. The success factors were agreed with the project team and board at the start of the option appraisal process.

Table 7 shows the Critical Success Factors, together with metrics for each factor, which have either been directly used in the development of the Strategy or provide a potential means of validating it in the future.

Table 7. Critical success factors for the Strategy

No.	Critical Success Factor	Measurement Criteria
1	To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks	- No. of people better protected against flooding over whole life of the Strategy - No. of residential properties at reduced risk of flooding immediately due to scheme and over whole life - No. of commercial properties at reduced risk of flooding immediately due to scheme and over whole life - No. of key infrastructure assets protected
2	To facilitate sustainable growth of Bristol and the wider wet of England economy by supporting development opportunities for employment and residential land, and associated infrastructure	- m2 of new employment area generated - No. of new residential dwellings vs. current plan - No. of new key infrastructure assets better protected. - Length of flood risk management infrastructure delivered through redevelopment
3	To maintain, and where possible enhance, natural, historic, visual and built environments	- No. net loss of key habitats (and any enhancements) - Compliant with environment regulations and legislation - No. cultural heritage assets at reduced risk of flooding
4	To ensure navigation of the River Avon and marine activities can continue	- No. of vessel journeys affected - Continuation of existing activities
5	Ensuring that the Strategy is technically feasible and deliverable over its duration	- Delivery of Strategy - Planning permission granted - Positive benefit : cost for the investment - Required contributions secured

3.3 Long list options

3.3.1 *Long list measures*

Each strategic option comprised a series of feasible, coherent and logical measures to manage flood risk over the next 100 years. Initially a wide variety of measures were identified, however a number of measures were discounted as they were not considered technically viable for managing the flood risk specific to the study site.

The measures taken forward and included in the strategic options included:

- ‘Low’ defences – constructing new defences in these locations, to a 1:200 year (0.5% AEP) standard of protection for 2030, as an interim measure
- ‘High’ defences – constructing defences to a 1:200 year (0.5% AEP) standard of protection for 2115. Implemented by constructing a new defence or raising a low defence.
- Local scale measures - property protection and temporary defences

- Wide tidal barrier – construction and operation of a tidal barrier across a ‘wide’ section of the River Avon downstream of Bristol. The wide barrier location was chosen as Pill and Shirehampton, approximately 500m upstream of the M5 road bridge.
- Narrow tidal barrier – construction and operation of a tidal barrier across a ‘narrow’ section of the River Avon downstream of Bristol. The narrow barrier location was at Ham Green / Nibley Road, approximately 1500m upstream of the wide barrier location.
- Do Minimum – represents what would happen if the ‘status quo’ is maintained. This involves continued maintenance of all existing defences and the existing Floating Harbour water level control structures, but no new defences and no raising of defences.
- Do Nothing – a cessation of all maintenance and operations, with gates assumed to be in open position. Not considered an acceptable or viable long term approach in Bristol but it was included as it provides a hypothetical baseline against which all other measures and strategic options could be compared.

3.3.2 *Long list options*

Once the measures had been identified the strategic options were developed. For each option a measure was assigned to each time epoch, so for instance a strategic option could have comprised various local scale measures in epoch 1, construction of low defences in epoch 2 and then upgrading to high defences in epoch 3.

To ensure that this stage of the appraisal was robust, and that each potential combination of measures was considered, an ‘options tree’ was created which mapped each potential sequence of measures. From here, the impractical or illogical combinations were discounted and scoped out from further consideration. In total 39 different sequences remained on the tree, with each of these sequences considered to be a practical strategic option.

3.3.3 *Long to short list appraisal*

Each measure and long list option was developed sufficiently in terms of concept and spatial influence and potential form to ensure an adequate understanding of potential option impacts. This allowed a robust appraisal of options to be undertaken with sound decision making.

High level costs for each measure were established to enable a relative cost comparison of the different options. A high level environmental assessment was also undertaken to determine the possible environmental impacts of each measure and long list option.

The long to short list appraisal was based on a multi-criteria assessment whereby each long list option was scored against the option objectives (agreed by key stakeholders, the project team and board, and described in section 2.4). For more details on this process, refer to the Short List Options Report.

Three key outcomes from the appraisal process were: rejection of the Wide Barrier measure, restriction of PLP/Temporary barriers to epoch 1, and a preference for adaptive measures (which provide flexibility to adapt to climate change and resulting sea level rise) over precautionary options (which implement measures now to address all projected impacts of climate change up to 2115).

The Wide Barrier measure failed to make it onto any of the short list options, for the following reasons:

- Highest cost: The Wide Barrier measure had the highest capital costs of any measure, with estimated costs in the range of £550-600million (capital cash costs). This was picked up in the multi-criteria appraisal with options that include the wide barrier generally being ranked amongst the lowest for this category. An indicative partnership funding calculation for the Wide Barrier indicated GiA contributions would be less than 20% for this measure. Potential multiple uses and functions of a barrier, including harnessing tidal energy or providing an additional transport link were explored but were not shown to sufficiently improve the economic case or reduce the potential funding gap.
- Environmental impact: The Wide Barrier, being located adjacent to key environmental designations, was found to be likely to produce the most significant environmental impacts of any measure. The environmental assessment identified that the Wide Barrier is likely to have a significant impact on receptors such as Landscape and Visual, Terrestrial Ecology, Estuarine and River Ecology, Archaeology and Heritage, Geomorphology and Water Quality and Traffic and Transport.
- Deliverability risk: The Wide Barrier poses significant deliverability risk with challenges expected to arise in acquiring the necessary consents, especially those which may relate to environmental

impacts with the barrier being located so close to the environmental designations. A barrier would also need to acquire a Transport and Works Order which could pose a significant deliverability risk.

- In overall terms the benefits of the Wide Barrier were found to be achievable through implementation of a Narrow Barrier, and to some extent, via the High Defences measure (as this also provides a high long term standard of protection to central Bristol). These alternative measures have less negative impacts than the Wide Barrier, yet provide a similar level of benefits.

The PLP and temporary / demountable measure made it onto a number of the shortlist options. However, it was not considered a long term solution and was only included in epoch 1 for the options which made it to the short list. In these options it can be thought of as an ‘interim’ solution until a more substantial ‘Do Something’ measure is implemented, such as Low Defences, High Defences or a Narrow Barrier.

The resulting short list was comprised of seven strategic options (denoted A-G), in addition to the Do Nothing and Do Minimum scenarios. The short list options, alongside a brief description of what measures they include are presented in Table 8 below.

Table 8. Short list options

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 1 in 200 year (0.5% AEP) standard in 2030.	Additional linear flood walls built to protect Bristol to a 1 in 200 year (0.5% AEP) 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 1 in 200 year (0.5% AEP) standard to 2115.	Walls maintained, standard falls over time to 1 in 200 (0.5% AEP) 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 1 in 200 year (0.5% AEP) standard or higher, for the next 100 years	Barrier maintained, standard falls over time to 1 in 200 (0.5% AEP) or higher
D	Low Defences – Low Defences – High Defences	Linear flood walls built to protect Bristol to a 1 in 200 year (0.5% AEP) standard or higher for 2030.	Walls maintained, standard falls over time.	Additional linear flood walls built to protect Bristol to a 1 in 200 year (0.5% AEP) standard or higher 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 1 in 200 year (0.5% AEP) standard or higher for 2030.	‘Narrow’ tidal flood barrier built to protect Bristol to a 1 in 200 year (0.5% AEP) standard or higher, for the next 100 years	Barrier maintained, standard falls over time to 1 in 200 (0.5% AEP) or higher
F	High Defences-	Linear flood walls built to protect Bristol to a 1 in	Walls maintained	Walls maintained, standard falls over time

Option	Option Title	Epoch 1 (2015-2030)	Epoch 2 (2030-2065)	Epoch 3 (2065-2115)
	High - High	200 year (0.5% AEP) standard or higher for 2115.		to 1 in 200 (0.5% AEP) in 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 1 in 200 year (0.5% AEP) standard or higher until 2115

*PLP refers to property level protection and temporary flood defences. Property level protection is a generic term for permanent flood defences fitted to individual properties, such as property barriers, non-return valves and airbrick vent covers. Temporary or demountable defences are removable defences or require operation/deployment during flood events and typically protect a number of properties at once.

3.4 Measures comprising the short list options

This section provides a more detailed explanation of the measures which comprise the short list options.

3.4.1 *Do Minimum*

Description

Do Minimum as a standalone measure is included in Option G only. It is assumed that Do Minimum includes continued operation of the Floating Harbour and hence involves a continuation of maintenance to both the Floating Harbour water level control structures and existing raised defences. Under the Do Minimum scenario like-for-like replacement of mechanical infrastructure e.g. lock gates is undertaken but no improvements in performance to account for sea level rise.

Technical assessment

Do Minimum is technically viable given that it represents a continuation of existing activities.

Do Minimum provides a flood risk benefit compared to Do Nothing, but it does not account for sea level rise and the standard of flood protection in the strategy area would fall over time. Do Minimum is considered feasible in the short term but is considered to be unfeasible over the full appraisal period. This is because, over time, operation of the Floating Harbour (particularly at low spots such as Underfall Yard) during extreme events becomes less realistic with risk of debris / car / boat impacts preventing operation, and difficulties expected in maintaining access and power to key operational assets.

Currently there is a lack of information available to indicate the residual life of the key harbour assets and the increased vulnerability due to sea level rise. A separate commission to provide this key information is planned for 2018 (the Harbour Asset Management Strategy). Once this data is available a more informed assessment of harbour operation in the future will be made.

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.
- There is a high likelihood and catastrophic consequence of debris on the operation of the Floating Harbour.
- Recent investment has increased the resilience of Junction Lock, Entrance Lock and Nova Dam but damage to Underfall Yard and Brunel Dam would hinder the Harbour’s operation following or during a flood.
- Netham Lock was considered resilient from a mechanical perspective the BCC Harbour Master has noted the 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.

Environmental assessment

Do Minimum is likely to have a minimal environmental impact, except that there would be a negative socio-economic and heritage impact as standards of flood protection fall over time. The quality of life for residents would be adversely impacted and investment in the city deterred.

Table 9. Summary of environmental impacts of Do Minimum.

	Biodiversity	Assets and health	Soil / water	Climatic factors	Cultural heritage	Landscape
Construction	No negative impact	Minimal as typically localised patch and repair maintenance or continuation of current operations.	No negative impact	No negative impact	No impact	No negative impact
Operation	No negative impact	Negative impact– detrimental impacts due to increasing flood risk	No negative impact	No negative impact	Minor impact – potentially experience increased flooding.	No negative impact

3.4.2 *Property level protection and temporary / demountable defences*

Description

Property level protection and temporary / demountable defences are included in options A, B and C. PLP is a generic term for permanent flood defences such as individual property barriers, non-return valves and airbrick/vent covers fitted to individual properties or groups of properties such as blocks of flats. Typically PLP can provide protection from flooding to individual properties at very significant risk up to approximately 600mm of water depth (though greater depths can be accommodated through use of customised flood barriers). For flood depths greater than 600mm, PLP is unlikely to form an effective defence. For this reason PLP can provide only a relatively low standard of protection and defining the exact standard of protection for large areas is difficult given that flood depths vary across the city from the same magnitude events.

Temporary / demountable defences are moveable flood protection systems that are deployed or raised during flooding conditions. Temporary / demountable defences are designed to protect large areas or groups of properties.

Technical assessment

This measure would include the provision of different PLP and temporary / demountable defence zones across the study area. This is technically viable; PLP measures would be delivered on a property by property basis and temporary / demountable defences would be delivered on a local scale. To successfully deliver this measure it would be necessary to provide on-site storage of the temporary defences and provision of a specialist team responsible for the deployment of the defences.

Environmental assessment

The environmental impacts of PLP and temporary / demountable defences are likely to be limited to minor impacts on the appearance of heritage buildings and the population given the measure does not provide a high standard of flood protection. The environmental impacts of PLP are summarised in Table 10 below.

Table 10. Summary of environmental impacts of PLP

	Biodiversity	Assets and health	Soil / water	Climatic factors	Cultural heritage	Landscape
Construction	No negative impact	Minor impact – temporary negative effects particularly for heritage assets	No negative impact	No negative impact	No impact	No negative impact
Operation	No negative impact	Minor impact – option does not provide a high standard of protection	No negative impact	No negative impact	Minor impact – PLP would help ensure asset itself is not flooded but would not protect the setting	No negative impact

3.4.3 *Low defences*

Description

Low defences are included in options A, D and E. The Low Defence measure comprises linear defences – walls or embankments – to provide a 1:200 year (0.5% AEP) standard of protection until 2030. The defences will be robust against short to medium term sea level rise but at a future point in time the defences will need to be raised further or an alternative measure implemented in order to sustain a high standard of protection. Low Defences represent a more adaptive solution to manage tidal flood risk and sea level rise.

The implementation of Low Defences involves identifying low spots or gaps in the existing defences and then raising the existing defence levels or constructing new floodwalls or similar defences (e.g. embankments) in these locations.

Technical assessment

Approximately 4.7km of new flood defences will be required in central Bristol; at Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown / St. Phillips and Netham. As part of the low defence measure new tidal stop gates and supporting infrastructure will also be required at Entrance Lock and Netham Lock. The average height of the low defences in central Bristol ranges from 0.7m to 1.1m above ground level. Outside of the central area, low defences will also be needed at Pill and Shirehampton although these have been treated as separate schemes to the works required in central Bristol.

In conjunction with the construction of Low defences, 1.5km of new defences will be required upstream of Netham and at Bower Ashton on the south bank of the River Avon to prevent adverse flood impacts in these areas (the impacts arising from constraining the channel elsewhere).

An outline design of the low and high defences has been undertaken during the Strategy and has shown that the low defences are technically viable. There would be synergies with harbour asset management and other activities associated with low defences, such as the management and operation of the flood / lock gates at the entry points to the Floating Harbour and the retaining function for Highways along the New Cut (e.g. Clarence Road).

Environmental assessment

There are positive and negative environmental impacts of Low defences. The defences will provide a positive socio economic benefit through a reduction in flood risk. However, the defences are likely to have minor landscape and visual impacts, minor impacts on heritage buildings and during construction there are likely to be temporary impacts on ecology, soil/water and local traffic. Suitable mitigation includes timing construction works appropriately and landscaping. If urban realm/greenway enhancement solution cannot be achieved, the intervention could have negative visual and landscape impacts.

Table 11. Summary of environmental impacts of Low defences

	Biodiversity	Assets and health	Soil / water	Climatic factors	Cultural heritage	Landscape
Construction	Temporary negative impact on wildlife corridors	Temporary negative impacts – transport disruption	Temporary negative impact – disturbance of river bed and release of sediment	Minor impact – greenhouse gas emissions from construction	Temporary negative impact – a number of heritage assets	Temporary negative impact – dust, visual etc.
Operation	No negative impacts	No negative impacts	No negative impacts	No negative impacts	Impacts on historic character of city	Impacts on visual character of area

3.4.4 *High defences*

Description

High defences are included in options A, B, D, F and G. The implementation of high defences involves identifying low spots or gaps in the existing defences and then raising the defence crest levels or constructing new floodwalls or similar defences (i.e. embankments) in these locations.

The design standard of protection for the high defences is a 1:200 year (0.5% AEP) standard at 2115 and therefore the high defences represent a precautionary management approach and provide robust long term protection from tidal flood risk by considering sea level rise and climate change projections until 2115. Being a precautionary measure, high defences could be constructed in epochs 1, 2 or 3 and irrespective of the timing the protection provided by the defences will exceed the 1:200 year (0.5% AEP) standard for the duration of the strategy period (the defences are designed so that the standard gradually falls to a 1:200 year (0.5% AEP) standard by 2115 due to sea level rise). If sea level rise was not to occur, there is the risk that the High defences would be overdesigned.

Technical assessment

The locations of the high defences are the same as low defences. Stop gates and operational infrastructure at Entrance Lock and Netham Lock would also be required.

An outline design of the high defences has been undertaken during the Strategy and has shown that the raised defences are technically viable. In some instances where land availability and space is limited for the implementation of high defences in epoch 3 it may be necessary to work alongside landowners / developers to facilitate construction.

Environmental assessment

There are positive and negative environmental impacts of High defences. The defences will provide a positive socio economic benefit through a reduction in flood risk. However, the defences are likely to produce impacts on heritage buildings and during construction there are likely to be temporary impacts on ecology, soil/water and local traffic. There are also likely to be significant landscape and visual impacts because the high defences will form a physical barrier between the land and New Cut channel.

Suitable mitigation includes timing construction works appropriately and landscaping. If urban realm/greenway enhancement solution cannot be achieved, the intervention could have negative visual and landscape impacts.

Table 12. Summary of environmental impacts of High defences

	Biodiversity	Assets and health	Soil / water	Climatic factors	Cultural heritage	Landscape
Construction	Temporary negative impact on wildlife corridors	Temporary negative impacts – transport disruption	Temporary negative impact – disturbance of river bed and release of sediment	Minor impact – greenhouse gas emissions from construction	Temporary negative impact – a number of heritage assets	Temporary negative impact – dust, visual etc.
Operation	No negative impacts	No negative impacts	No negative impacts	No negative impacts	Impacts on historic character of city	Impacts on visual character of area

3.4.5 *Narrow Tidal barrier*

Description

The Narrow Barrier measure was included in options C and E. A tidal flood barrier would operate to exclude the highest surge or astronomical tides which otherwise could cause flooding in the city centre. For most of time the barrier gates would be in the open position, allowing largely unimpeded flow of water in the tidal Avon and normal tidal variation.

The proposed barrier location was across the River Avon between the amenity grassland area adjacent to Nibley Road, Shirehampton and the river bank immediately downstream of the Chapel Pill confluence at Ham Green. This is a so-called 'Narrow' barrier location, to distinguish it from the much wider barrier configuration that would be required further downstream.

A 'Wide' barrier, located further downstream, was discounted at the shortlisting stage due to its significantly higher cost and greater potential for negative environmental impact. An alternative 'Narrow' location immediately downstream of Cumberland Basin was also discounted at shortlisting stage as numerical modelling suggests it could increase fluvial flood risk in the city centre.

As part of the tidal barrier measure, the approach would also require flood walls to be constructed upstream of the barrier in central Bristol. These walls would be needed to increase the storage capacity of the upstream channels for periods when the tidal barrier was closed and to stop the stored water from overflowing and flooding the surrounding areas. In terms of the potentially negative visual impacts in the city centre the tidal barrier therefore has little benefit over the raised defence measures because flood walls would still be constructed throughout the city.

Technical assessment

An outline design for a tidal barrier at Ham Green – Nibley Road was developed during the Strategy. The design consists of 3 gates, ranging in width from 25 to 40m and in height from 10 to 18m. Construction of a barrier is technically feasible, but there are a number of risks associated with its delivery. These include:

- Ground conditions – a marine ground investigation using a jack-up barge would be needed. Ground investigation information may lead to a need to re-site the barrier or change it configuration
- Land acquisition – a barrier will need significant compound space, room for a control building and access roads on both banks. There are risks with land acquisition
- Planning consent and other consenting issues – the barrier may be taken through the major projects planning process or a Transport and Works Act Order (TWAO) will be required as the barrier will impact on river navigation. If there are objections to the proposals a public enquiry may be required. There is likely to be a need for other consents, such as from the Marine Management Organisation.
- Lead time – a barrier project of this magnitude might theoretically be implemented within 6 years, but more realistically would take 10-15 years. An early decision is required with realistic allocation of funding, if the project is to be operational by 2030.
- Geomorphological impacts – it is likely that a barrier would alter the water flows, disturb sediment and mudbanks in the area and potentially impact the geomorphology of the river bed.
- Access – construction and operational constraints to access to/from the left bank (Pill). Using this access would have significant local impacts and would therefore increase the costs.

Environmental assessment

The environmental impacts of a Tidal Barrier are potentially widespread and significant. A barrier could have significant permanent impacts on ecology and nearby sensitive habitats (i.e. SPA, SAC, Ramsar and SSSI sites). A barrier could also impact the setting of heritage buildings, the geomorphology of the River Avon channel and during construction there could be temporary impacts on local traffic.

Table 13. Summary of environmental impacts of Tidal Barrier

	Biodiversity	Assets and health	Soil / water	Climatic factors	Cultural heritage	Landscape
Construction	Significant negative impacts – environmental designations in proximity. Noise and other disturbances	Negative impacts – localised noise, dust, traffic, river flows, sediment loads	Temporary negative impacts – disturbance of river bed and release of sediment	Minor impact – greenhouse gas emissions from construction	Temporary effect – setting of heritage assets	Temporary negative impact - dust, visual etc.
Operation	Negative impacts – potential for changes in water velocity and impacts on fish	Temporary minor impacts – navigability	No negative impacts	No negative impacts	No negative impacts	Impact on key viewpoints. Debatable whether negative or positive

3.5 Economic appraisal

3.5.1 *Damages and Benefits*

Direct

To establish the benefits of the 'Do Something' options it was necessary to first determine the direct flood damages to properties and assets under the 'Do Nothing' and 'Do Minimum' options scenarios.

The 'Do Minimum' scenario represents the existing 'status quo' and is described in more detail in section 2.1.2.

Do Nothing is a hypothetical 'walk away' scenario in which it is assumed that all maintenance, repair and renewal work of existing flood defences would cease immediately. The operation of the water level management assets would also cease (e.g. lock gates, sluices and lock systems). Under this scenario the flood stop gates and lock gates at Junction Lock and Netham have been assumed to have a default open position. Leaving the gates closed would prevent use of the Floating Harbour as a refuge – a legal duty – and lead to flooding due to inflows.

The CAFRA WS3 hydrodynamic model was run with the Do Nothing and Do Minimum scenarios for a range of % AEP events through time including 50% AEP (2yr), 5% AEP (20yr), 1.33% AEP (75yr), 0.5% AEP (200yr) and 0.1% AEP (1000yr) return periods.

Property flood depths were converted into damages by applying the methodologies set out in the Multi-coloured Manual (MCM, 2015). For this appraisal, a 'Short duration, major flood of salt water' classification was adopted. Emergency costs were applied for residential properties.

Indirect

In addition to direct asset damages and benefits, a range of relevant intangible damages and benefits were also quantified following the FCERM Economic Handbook, Multi Coloured Manual (MCM, 2016) guidelines. This included traffic disruption, health impacts, vehicle damage and loss of life risk.

The critical highway network in Bristol is often near or at capacity and the whole network is vulnerable to disruption from even a minor incident at rush hour periods. Therefore flood risk poses a major threat to local and regional highways links. To support and underpin the quantification of damages and benefits associated with transport, CH2M provided a Tidal Flood risk Transport modelling report (2016) and this was utilised to incorporate these benefits into the economic case for the Strategy.

Health impacts including stress and anxiety can be monetarised per event and this, along with emergency costs associated with flooding were also assigned in the benefit appraisal.

Vehicle damages (£3,100 per vehicle) were also captured in the assessment, based on MCM guidelines which assume 28% of properties which flood have a vulnerable vehicle.

Loss of Life impacts were valued utilising a Defra monetary valuation of risk to life and an assessment of flood hazard, population and vulnerability indices to estimate the total value associated with this category.

A summary of the option benefits is provided in Table 14. For further information on methodologies and assumptions applied in the valuation of benefits refer to the Strategy Economic Reports.

Local economic impact

In addition to direct and indirect flood damages an assessment was also made of GVA losses in a Do Nothing scenario and it was found that these could total 2.5 times the FCERM direct and indirect damages (assessed as a loss to the nation). A significant proportion (80%) of the GVA impacts stem from the likely lost opportunity (development, employment and investment) which would otherwise bring local benefit to the economy if it were not to be inhibited by unmitigated tidal flood risk.

It was assumed in the GVA assessment that without flood risk infrastructure to adequately mitigate flood risk, the future projected jobs and employment within both the Temple Quarter Enterprise Zone and the wider city area would not occur.

3.5.2 *Costs*

The costing of options was carried out following a 'bottom up' approach, whereby costs for the separate measures in each epoch have been estimated and then summed to derive the total costs for the

Strategic Option. Once cash costs were derived it allowed for whole life present value costs to be developed for each of the options following standard HM Treasury discounting rates. A 60% optimism bias was applied in line with FCERM-AG recommendations for Strategic level studies.

Costing was carried out using a variety of sources and utilising best available information. For the initial costing at long list stage the costs were based on rates for unit lengths of defences. As the appraisal progressed, indicative cross sections were used and more detailed costing was undertaken at the later stages (e.g. preferred option stage).

At various stages throughout the appraisal a cost assurance was provided to the Council by Arcadis who independently costed the options and cross checked against the estimates provided.

More details on costing can be found in the Preferred Options Report.

Do Minimum

The cost estimate for do minimum was based upon real life costs for operation of the Floating Harbour, provided by Bristol City Council (BCC) and the Harbour Master, costs for the emergency deployment and operation of temporary defences, and costs provided by BCC for the maintenance of flood defence assets in central Bristol, Pill and Shirehampton.

Initially, annual costs associated with this option were estimated to be £76k, but due to increasing sea levels, ageing of assets and a greater maintenance burden this moves to £172k per annum by year 100.

Property level protection and temporary / demountable defences

An average cost per property for PLP measures was assumed based on real costs from a 49 property resistance scheme at Wallington (Fareham) on the south coast of the UK. Additional information from Environment Agency published literature, Defra Pilot studies and quotations for commercially available defences from direct contractor discussion (UK Flood Barriers) were also used. The worked up estimates of the costs were £4,250 per property (excluding optimism bias).

Costs for temporary barriers / demountable defences were estimated at a high level by assuming a cost equal to that of PLP based on the number of properties protected.

Raised defences (low and high defences)

For the purpose of the short list appraisal costs a number of conservative assumptions were made to derive ‘worst case’ costs. Costs were then built up from SPONS (2015) based on the lengths and heights of defences required.

Raised defences typically comprise sheet piling type solutions with costs ranging from £10 – 18k per metre.

Unit costs were then checked and benchmarked against the Environment Agency PCT cost database and were found to be within 10% of each other, thereby improving confidence in the cost estimates.

Tidal barrier

The cost of a tidal barrier was based on benchmarking and pro-rating scale against other tidal barrier schemes (e.g. the Thames Barrier) that have been undertaken elsewhere. The wider barrier costs estimate approximately £600m, with narrow barrier options costed at over £300m - 420m.

3.5.3 ***Present values***

The FCERM-AG standard annual discount rates of 3.5% for the years 0 to 30, 3% for the years 31 to 75 and 2.5% for the years 76 to 99 were applied to derive present value option costs and benefits. For a breakdown of the present value option costs, see Table 14.

Table 14. Summary of economic benefits of options

	Do Nothing	Do Minimum	Option A (PLP-Low-High)	Option B (PLP – High)	Option C (PLP-Barrier)	Option D (Low – Low – High)	Option E (Low – Barrier)	Option F (High)	Option G (Do Min – Do Min – High)
Damages (PV £m)	1,631	315	85	71	59	55	32	33	201
Benefits (PV £m)	0	1,316	1,546	1,560	1,572	1,576	1,599	1,598	1,430
Whole life costs (PV £m)	0	24	113	130	471	166	595	202	57

Table 15. Summary of present value costs of options (£m) including 60% optimism bias

	Do Minimum	Option A (PLP – Low – High)	Option B (PLP – High)	Option C (PLP – Barrier)	Option D (Low – Low – High)	Option E (Low – Barrier)	Option F (High)	Option G (Do Min – Do Min – High)
Capital costs (Studies, Design & Construction)	0	89	101	410	138	536	165	33
Future costs (Operations and Maintenance)	24	24	29	61	28	59	37	24
Project total costs (present value)	24	113	130	471	166	595	202	57

3.5.4 *Option ranking and economic appraisal*

Approach

Based upon the decision making rules set out in FCERM-AG, the options were organised by the extent to which they reduce the probability of flooding.

Given that each option comprises a sequence of measures whose standard of protection varies, it was difficult to rank the options using an average standard of protection for the full appraisal period. Therefore the total costs and benefits of the strategic options were used as a proxy for the standard of protection provided by the options and they were organised on this basis. Once ranked, the option with the highest average benefit cost ratio (ABCR) was identified as the provisional leading economic option.

Once the leading economic option was identified the incremental benefit cost ratio (IBCR) of the options was considered to determine if there was a justification for increased investment. The IBCR is defined as the difference in the benefit between two options, divided by the difference in cost. If the IBCR is >1, it demonstrates that there will be a greater return from the additional investment from one option to the next. The IBCR was calculated between groups of options based on the overarching approach to managing the flood risk; Do Minimum, raised defences or a tidal barrier.

In FCERM-AG there a set of IBCR thresholds which are used to identify the preferred standard of protection for a scheme. Given that the strategic option comparison is not comparing like-for-like schemes this stage of comparison was not considered to be the appropriate time to compare against the IBCR thresholds. Instead section 3.9.2 later in this report discusses the IBCR thresholds for the initial schemes that have emanated from the preferred strategic option and provides the justification for choosing the recommended standard of protection for the schemes.

Option ranking and choice of the leading economic option

Table 16 presents the seven shortlisted options in order of reduced probability of flooding (i.e. those providing the lowest standard of protection at the top with an increasing standard moving down the list). Also presented is the do minimum scenario.

Table 16. **Strategic option costs and benefits**

Category	Strategic option	Sequence of measures	Economic costs PV (£m)	Economic benefits PV (£m)	ABCR	IBCR	Provisional leading economic option
Do Min	NA	Do Min – Do Min – Do Min	24	1,316	56:1	/	×
Raised defences	G	Do Min – Do Min – High Def	57	1,430	25:1	1.6 - 3.4	✓
	A	PLP – Low Def – High Def	113	1,546	14:1		×
	B	PLP – High Def – High Def	130	1,560	12:1		×
	D	Low Def – Low Def – High Def	166	1,576	9:1		×
	F	High Def – High Def – High Def	202	1,598	8:1		×
Barrier	C	PLP – Barrier – Barrier	471	1,572	3:1	< 0.3	×
	E	Low Def – Barrier - Barrier	595	1,599	3:1		×

As shown in Table 16, the provisional leading economic option when based upon the ABCR was strategic option G. This option had the highest ABCR of the options with an estimated PV cost of £57million and PV benefits of £1,430 million (ABCR of 25:1).

Note that the options including raised defences in the city centre will also produce benefits against fluvial flood risk. However this aspect has not been quantified at this stage and therefore fluvial benefits are not included in the benefits stated in Table 16. The inclusion of fluvial benefits would increase the benefits associated with options G, A, B, D, F, and E (low defences in epoch 1).

IBCR of barrier options

The IBCRs of moving from raised defence options to barrier options (options C and E) are < 0.3. In fact, moving from option F (high defences option for epochs 1, 2 & 3) to option C (lowest cost barrier option) has a negative IBCR. This is because option C is significantly higher cost than option F, yet the whole life benefits are actually reduced as the barrier is not constructed until epoch 2 and flood damages can occur before this.

A set of additional IBCR calculations have been undertaken to separately compare the barrier options to the do minimum option. Table 17 presents the results of these calculations.

As demonstrated in Table 17, the IBCR ratios of the barrier options relative to do minimum are less than 1. This suggests that there is not an economic case to implement either barrier option as the increase in benefits from the barrier options relative to do minimum is less than the increase in cost.

Table 17. IBCR of barrier options relative to the Do Minimum approach

Strategic option	Sequence of measures	Economic costs PV (£m) (relative to Do Min)	Economic benefits PV (£m) (relative to Do Min)	IBCR (relative to Do Min)
NA	Do Min – Do Min – Do Min	NA	NA	NA
C	PLP – Barrier – Barrier	448	256	0.57
E	Low Def – Barrier - Barrier	572	283	0.50

Raised defence options

A set of IBCR calculations have been undertaken to separately compare the raised defence options A, B, D and F to the do minimum option (the scenario whereby do minimum is undertaken in each epoch). In these calculations the costs and benefits of the raised defence options are set relative to the do minimum scenario. Table 18 presents the results of these calculations.

Table 18. IBCR of raised defence options relative to the Do Minimum approach

Strategic option	Sequence of measures	Economic costs PV (£m) (relative to Do Min)	Economic benefits PV (£m) (relative to Do Min)	IBCR (relative to Do Min)
NA	Do Min – Do Min – Do Min	NA	NA	NA
G	Do Min – Do Min – High Defences	33.0	114.0	3.45
A	PLP – Low Def – High Def	89.0	230.2	2.59
B	PLP – High Def – High Def	106.6	244.2	2.29
D	Low Def – Low Def – High Def	142.6	260.2	1.82
F	High Def – High Def – High Def	178.3	282.2	1.58

As shown in Table 18, the IBCR of each of the raised defence options (A, B, D, F and G) relative to do minimum is greater than 1. This demonstrates an economic case to undertake each of these options (relative to do minimum) as the additional benefits produced by the options compared to do minimum outweigh the increase in costs.

An additional set of IBCR calculations have been undertaken, comparing the options which involve early investment in raised defences (epochs 1 or 2) compared to a delayed approach (epoch 3, option G). Table 19 presents the results of this comparison.

Table 19. IBCR comparison of early investment in raised defences to delayed investment (IBCR relative to option G – delayed investment)

Approach	Strategic option	Sequence of measures	Economic costs PV (£m) (relative to Do Min)	Economic benefits PV (£m) (relative to Do Min)	IBCR (relative to option G)
Delayed investment in raised defences	G	Do Min – Do Min – High Defences	33.0	114.0	/
Early investment in raised defences	A	PLP – Low Def – High Def	89.0	230.2	2.08
	B	PLP – High Def – High Def	106.6	244.2	1.77
	D	Low Def – Low Def – High Def	142.6	260.2	1.33
	F	High Def – High Def – High Def	178.3	282.2	1.16

The IBCR comparison shown in Table 19 shows that each of options A, B, D and F have an IBCR>1 compared to option G. This demonstrates that there is a case to construct the raised defences earlier rather than delaying the defences until epoch 3 (as in option G).

The conclusion from this solely economic assessment is that options C and E (the two barrier options) and Option G (which defers major works to epoch 3) should be discarded but that investment in any of options A,B,D and F would be justifiable.

3.6 Non-financial benefits appraisal

3.6.1 *Methodology*

The following objectives were set at the outset of the development of the Strategy, against which the Preferred Strategic Option has been tested:

1. To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks
2. To facilitate the sustainable growth of Bristol and the wider West of England economy by supporting development opportunities for employment and residential land, and associated infrastructure
3. To maintain, and where possible enhance, natural, historic, visual and built environments
4. To reduce whole life costs
5. To ensure navigation of the River Avon and marine activities can continue
6. Ensure the Strategy is technically feasible and deliverable over its duration

The non-economic criteria are focussed on reducing flood risk, technical robustness, continuation of navigation, environmental sustainability and facilitation of growth of Bristol.

Issues related to flood risk and technical robustness have been addressed in the development of the options.

All of the options are considered acceptable from a navigation perspective. The tidal barrier options are the only ones which present any significant potential impact on navigation, and the technical studies undertaken have shown that there are feasible designs which can be implemented without significantly constraining navigation.

The objectives for Environment and Growth are considered below in more detail.

3.6.2 *Objectives – Environment*

Environmental sustainability has been considered in the environmental assessment of each option, and as a whole in the Strategic Environmental Assessment (SEA).

The SEA has found that although all of the options have a potential for significant adverse impacts on quality of life and natural and built environments, whether temporary or permanent, there is also potential to mitigate or compensate for these impacts and an opportunity to provide enhancement as part of the design of all options.

The SEA has identified major issues that would need to be addressed, but has not identified a significant environmental reason for rejection – an issue so serious that it would lead to the outright veto of an Option.

Overall the SEA has found that there is not a clear ‘best option’ from an environmental perspective. The reason for this is that the barrier options concentrate their direct impacts on relatively small area, although the intensity of impact may be great. On the other hand the wall options will directly impact receptors over a large area. The impact of the barrier at distance is a current unknown, and would require some detailed investigations to resolve.

Similarly, some of the options have multiple phases, thereby potentially impacting adversely on several occasions, whereas others have fewer occurrences of impacts but these impacts might be more significant.

The preferred option will need to go through a formal planning/consenting process, with mitigation measures designed into both the permanent works and the construction plan.

3.6.3 *Objectives – Development opportunities*

One of the key objectives of the strategic options is to increase development opportunities and to facilitate sustainable growth of the Bristol and wider west of England economy.

All the raised defence options (A, B, D & F) support this objective as raised defences will provide a higher standard of protection against flooding which will reduce some of the potential constraints on development. For example, ground floor levels will not need to be raised as high and development will therefore be simpler and cheaper. A reduced flood risk will also enable different types of development to be pursued and will generally make the strategy area a more feasible location for developers.

In this respect, options D and F are preferable to options A and B in that they provide a strategic defence from epoch 1 rather than deferring it to epoch 2.

3.6.4 *Summary*

A summary comparing the barrier and raised defence options against the strategy objectives is shown in Table 20. It shows the barrier and defence options generally support the strategy objectives. Both groups of options are likely to have an impact on the environment. However, no significant environmental reasons for outright option rejection were identified in the SEA and both sets of options will need to address potential environmental impacts through suitable mitigation.

Table 20. Comparison of barrier and raised defence options against the objectives

Strategy objective	Barrier options (generic)	Raised defence options (generic)
1. To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks	🟢	🟢
2. To facilitate the sustainable growth of Bristol and the wider West of England economy by supporting development opportunities for employment and residential land, and associated infrastructure.	🟢	🟢
3. To maintain, and where possible enhance, natural, historic, visual and built environments.	🟠	🟠
4. To reduce whole life costs	🔴	🟢
5. To ensure navigation of the River Avon and marine activities can continue	🟠	🟢
6. Ensure the Strategy is technically feasible and deliverable over its duration	🟢	🟢
Key 🟢 Supports objectives 🟠 Mitigation required 🔴 Does not support objectives		

3.7 Selecting the preferred option

Options C and E, the strategic options with barrier measures, are not economically justified and the appraisal of non-economic benefits did not find a significant reason to select them over other options (even considering potential wider benefits, such as an additional transport link). Therefore these options were discarded.

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 Option G was discarded.

The economic case for Options A,B, D and F is very similar. However, Options D and F provide raised defences in epoch 1 rather than deferring to epoch 2. Earlier investment in defences better supports the key development / growth objective of BCC and will help to facilitate development opportunities in Bristol and wider growth within the region during epoch 1 (for example BCC plan to create 17,000 jobs in the TQEZ alone by 2037). BCC's objectives for the Strategy are a key consideration when selecting the preferred option and therefore in order to best support these objectives the choice of the preferred option was narrowed down to options D and F with Options A and B discarded.

Option D was selected over Option F for the following reasons:

- Lower cost, and significant part of cost deferred until 2065
- Option D defers high walls until 2065, deferring adverse visual impacts.
- Option D is more adaptable, with Low Defences in epochs 1 and 2 and High Defences only being built in epoch 3 if sea level rise projections come to fruition.

Table 21 summarises the results of the appraisal.

Table 21. Summary of appraisal

Option	Cost (£m)	Benefits (£m)	Economic appraisal	Wider benefit appraisal	Selection
A (PLP – Low – High)	113	1,546	Investment justified and additional investment compared to G also justified	No environmental reasons for outright rejection. Doesn't support growth during epoch 1	
B (PLP – High – High)	130	1,560	Investment justified and additional investment compared to G also justified	No environmental reasons for outright rejection. Doesn't support growth during epoch 1	
C (PLP – Barrier – Barrier)	471	1,572	Investment not justified	No environmental reasons for outright rejection but concerns over impact on natural environment. Supports growth from epoch 2.	
D (Low – Low – High)	166	1,572	Investment justified and additional investment compared to Option G also justified	No environmental reasons for outright rejection. Supports growth throughout More adaptable to sea level rise than Option F and lower cost	Preferred option
E (Low – Barrier – Barrier)	595	1,599	Investment not justified	No environmental reasons for outright rejection but concerns over impact on natural environment. Supports growth throughout	
F (High – High – High)	202	1,598	Investment justified and additional investment compared to G also justified	No environmental reasons for outright rejection but concerns over visual impact. Supports growth throughout	
G (Do Min – Do Min – High)	57	1,430	Investment justified	No environmental reasons for outright rejection but concerns over socio environmental impacts in epoch 2. Doesn't support growth during epochs 1 and 2	

3.8 Sensitivity testing

Sensitivity testing against key parameters and uncertainties has been carried out to ensure that the choice of preferred option remains robust to changes in the variables tested below.

3.8.1 *Barrier costs*

The cost of a tidal barrier was an essential reason why this measure was not included in the preferred option. Cash costs of a barrier were estimated to be between £550-600m. Sensitivity tests whereby the barrier costs were decreased by 50%, and also delaying the barrier until epoch 3 (and hence reduce the PV cost) have been undertaken, with the results summarised in Table 22.

The results show that should the barrier cost reduce by 50% the barrier options still remain significantly higher than the cost of the preferred option D. Likewise, by delaying the barrier until epoch 3, and hence reducing the overall PV cost of the barrier options, the costs still greatly exceed that of option D.

Table 22. Sensitivity tests – tidal barrier

Strategic Option	Sequence of measures	Test	Result
C and E	PLP – Barrier – Barrier Low – Barrier - Barrier	Reduce PV cost by 50%	Barrier options remain significantly more costly than Option D and have only a marginal benefit advantage. Option D remains preferred option.
C and E	PLP – Barrier – Barrier Low – Barrier - Barrier	Delay barrier to epoch 3	Reduces PV cost of the barrier to approximately £250m, but costs still greatly exceed Option D

3.8.2 *Raised defence costs*

If costs of raised defences were to increase by 25% then the impact would be similar across all five of these options and therefore the relative economic merits of each options would be largely unchanged. Should sea levels rise at a different rate to currently projected then the implementation time of high defences may need to be changed but because Option D is adaptive, it remains preferable in this case. The sensitivity tests for the raised defences are shown in Table 23 below.

Table 23. Sensitivity tests – raised defences

Strategic Option	Sequence of measures	Test	Result
A, B, D, F & G	PLP – Low – High PLP – High – High Low – Low – High High – High – High Do Min – Do Min – High	Cost increase by 25%	Would affect all Low / High Defence options to same extent. Relative merits largely unchanged but funding gap would increase.
A, B, D, F & G	PLP – Low – High PLP – High – High Low – Low – High High – High – High Do Min – Do Min – High	SLR occurs faster than projected	High defences would need to be constructed earlier in appraisal period, but option D (adaptive) still more optimal the option F (precautionary)

Strategic Option	Sequence of measures	Test	Result
A, B, D, F & G	PLP – Low – High PLP – High – High Low – Low – High High – High – High Do Min – Do Min – High	SLR occurs more slowly than projected	Option D becomes remains optimal as it is adaptive and higher defences can be delayed – leading to no wasted investment

3.8.3 *Do Minimum*

The Do Minimum scenario / measure is based upon a number of assumptions regarding the failure of assets. It has been assumed that the maintenance of these assets and Do Minimum activities are carried out with all ‘Do Something’ options and therefore the impact of when asset fail on all the options is similar. The assumptions therefore have no impact on the choice of the preferred option.

3.9 The preferred option

Following the selection of the preferred option additional work was undertaken to further develop and refine the preferred option. The additional work was focussed on how to implement the preferred option in central Bristol only as this is where the majority of the flood benefits arise. The options at Pill and Shirehampton were not explored in any further detail and going forward to scheme implementation these will be treated as separate, standalone schemes. Information on flood risk in these areas is contained within the various option selection reports produced up to preferred option stage.

The following sections summarise the additional work that was undertaken in further development of the BCC scheme plans. For more detail, refer to the Preferred Option Development report.

3.9.1 *Defence phasing*

The preferred option (option D) specified the construction of low defences in epoch 1, maintaining these low defences in epoch 2, then raising to high defences in epoch 3. Additional work was undertaken to develop a phasing plan for the construction of the low defences to better match the onset of flood risk across the city. For more information on the updated phasing plan and the reasoning behind it refer to the Preferred Option Development Phase report. In summary the phasing plan involves:

Phase 1, in the short term, 2015:

- Construct low defences to the Floating Harbour flood cell at Entrance Lock, Cumberland Road underpass, Bathurst Basin Dam and Netham
- Construct low defences at Totterdown / St. Phillips

  Undertake localised works to existing defences at Bower Ashton, upstream of Netham and opposite Totterdown on the south bank and provide PLP at Bedminster. These elements are needed as more detailed modelling of the preferred option showed that the main works would raise water levels in the New Cut, which if not mitigated would lead to increased risk of flooding in these locations.

Phase 2, in 2030:

- Construct low defences at Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road (New Cut defences)
- Maintain the low defences around the Floating Harbour at Entrance Lock, Cumberland Road underpass, Bathurst Dam and Netham, and also at Totterdown / St. Phillips.

Phase 3, in the long term (notionally 2065 but capable of being brought forward or delayed according to the pace of sea level rise):

- Raise all low defences to high defences. This will be undertaken throughout: Entrance Lock, Cumberland Road, Cumberland Road underpass, Bathurst Dam, Commercial Road, Clarence Road, Cattle Market Road, Totterdown / St. Phillips and Netham.

Key Plan 2 shows the location and phasing of the defences. The preferred option will reduce the flood risk to approximately 2000 residential properties and 1300 commercial properties over the next 100 years.

3.9.2 *Standard of protection*

The preferred strategic option recommends that the low defence schemes (phases 1 & 2) are constructed to a 2030 1:200 year (0.5% AEP) SoP and that the high defences in epoch 3 (phase 3) are constructed to a 2115 1:200 year (0.5% AEP) SoP.

Initially the SoP provided by the phase 1 scheme will exceed the 1:200 year (0.5% AEP) SoP. Between 2030 and 2065, if sea levels rise as expected the standard of protection will gradually fall from the 1:200 year standard (0.5% AEP). However the standard will remain above the 1:75 year (1.3% AEP) standard of protection by 2065. The exact time within epoch 3 when the defences are upgraded is flexible and the upgrade will involve crest raising of the low defences rather than starting the construction of high defences from scratch.

Table 24 presents the standard of protection provided by the preferred option through the appraisal period.

Table 24. Standard of protection provided by the preferred option

Time period	Defences	Standard of protection provided
Epoch 1 (2015 – 2030)	Low Defences	Initial > 1:200 year SoP. Falling to a 1:200 year SoP in 2030
Epoch 2 (2030 – 2065)	Low Defences	Initial 1:200 year SoP. Falling to a 1:75 year SoP in 2065
Epoch 3 (2065 – 2115)	High Defences	Initial > 1:200 year SoP. Falling to a 1:200 year SoP in 2115.

Constructing the phase 1 scheme to >1:200 year (0.5% AEP) SoP (present day) is recommended for a number of reasons:

- There is estimated to be a comparatively small cost difference between an initial 1:75 year (1.3% AEP) SoP and a >1:200 year (0.5% AEP) SoP. This is because the majority of the costs are associated with construction mobilisation and sections of the defence below ground level (i.e. the driving of sheet piles) which will also facilitate raising of the defences in the future.
- The 1:200 year (0.5% AEP) standard of protection better supports the wider benefits of the Strategy, such as encouraging development and investment in the city. It also better protects and safeguards existing businesses and better satisfies planning requirements.
- An even higher standard of protection (i.e. > 2030 1:200 year (0.5% AEP)) has not been selected because the rate of future sea level rise is uncertain and there is a risk of an overly precautious design. In addition, there are likely to be increased concerns relating to the visual impact of the defences should they be constructed to an even higher standard.

To demonstrate that the standard of protection recommended by the preferred option for the phase 1 scheme complies with FCERM decision rules the costs and benefits of the scheme with lower initial standards of protection have been estimated and compared against the IBCR thresholds.

Note that the costs of the lower SoP schemes have been approximated by scaling the costs of the recommended SoP. This high level approach provides an approximation only and therefore it is recommended that at the OBC stage the costs for lower SoP schemes are revisited and costed to a higher level of accuracy. Table 25 below presents the IBCR comparison against the FCERM IBCR thresholds.

Table 25. Phase 1 scheme IBCR comparison, 50yr appraisal period

Scheme	Whole life Cost (PV)	Whole life Benefits (PV)	ABCR	IBCR	IBCR threshold required	Preferred SoP
Do Minimum	£1,850k	£911,000k	492	/	/	
Present day 1:75yr	£42,850k	£988,000k	23	2	1	
Present day 1:200yr	£45,000k	£1,024,000k	23	17	3	
Present day >1:200yr	£46,150k	£1,032,000k	22	7	5	✓

The IBCR assessment shown in Table 25 suggests that the choice of standard of protection for the phase 1 scheme is justified because the IBCR of 7 exceeds the required threshold (of 5). Note that the amount of GiA available to help fund a scheme is likely to be capped at the cost of delivering the scheme to the preferred SoP based on FCERM decision rules and the IBCR comparison. It is recommended that the IBCR assessment is updated at OBC stage.

Standard of protection with respect to planning

For the purpose of FCERM the standard of flood protection for the proposed defences is determined by the design water level, excluding freeboard. However the defences include an additional 200mm allowance (freeboard) to cover uncertainty – see Outline Design Report for details on how this required tolerance was defined.

For the purpose of planning and development the freeboard applied on the strategic raised defences can be effectively counted as producing a higher defence standard which complies with NPPF requirements (see **Figure 9**). This is because all new development will still apply threshold raising on a site by site basis to deal with uncertainty even with the Strategy in place; therefore the total height defences can be considered for the effective standard of protection from a planning perspective and this provides a 1:200 year (0.5% AEP) standard of protection throughout the appraisal period (assuming sea levels rise as projected).

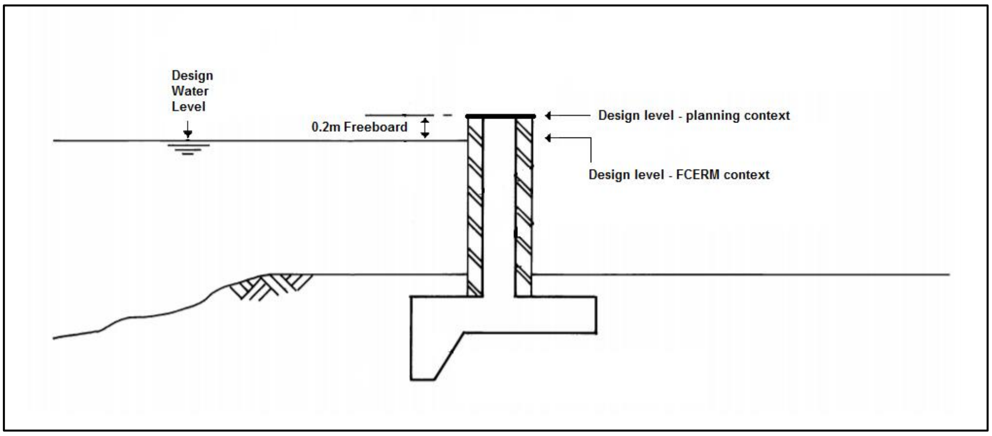


Figure 9. **Illustrative summary sketch (not actual defence details) showing the difference between planning and FCERM defence design levels and freeboard allowance**

3.9.3 *Adaptive Capacity*

The preferred option sets out the timescales / time epochs for various schemes over the next 100 years. When developing the Strategy the epochs provided the basis from which to appraise the various options and to identify the preferred approach.

However, the Strategy is adaptive and there is a degree of flexibility with regard to implementation timing and design for future schemes. For instance, decision makers may decide that schemes may need to be brought forward in time or delayed depending on the actual rates of sea level rise of the occurrence of development opportunities.

To inform the decision making process a number of threshold ‘triggers’ for implementation have been identified.

Sea level rise – trigger levels

The recommended FCERM change factor for climate change has been adopted (UKCP09 Medium Emission Scenario 95%tile) and this underpinned the Strategy development and economic appraisal. However, sea level rise projections are inherently uncertain and over the next century sea levels could rise more rapidly or more slowly than expected.

Low defences are scheduled to be constructed from the present day and therefore a sea level rise trigger is not needed for this set of schemes. However, for high defences, a sea level rise ‘threshold trigger’ is needed because these are scheduled for 2065 and sea levels could rise faster or slower than expected. The trigger for high defences depends upon the standard of protection provided by the preceding low defences and how this falls over time.

From 2030 the initial 1:200 year (0.5% AEP) SoP provided by the low defences is expected to gradually fall and based on the sea level rise projections the standard is expected to be just above a 1:75 year (1.3% AEP) by 2065 (the significant risk band).

The 2065 1:75 year (1.3% AEP) in-channel water level adjacent to the proposed defences is between 9.35-9.40m ODN. This water level would be caused by tide levels of approximately 9.26m at Avonmouth which is approximately 0.3m higher than the equivalent (1:75, 1.3% AEP) present day level.

Based on this analysis, if sea levels rise faster or slower than projected a suitable trigger for the implementation of the high defences is when mean sea level rises by 0.3m (compared to present day).

By constructing high defences at this trigger threshold, it will ensure that the preferred option would provide the standard of protection that it would otherwise deliver if sea levels rise as projected, and this would also ensure that the properties protected by the defences would not fall into the significant risk band. Refer to **Figure 10** for a graphic representation of the sea level rise triggers.

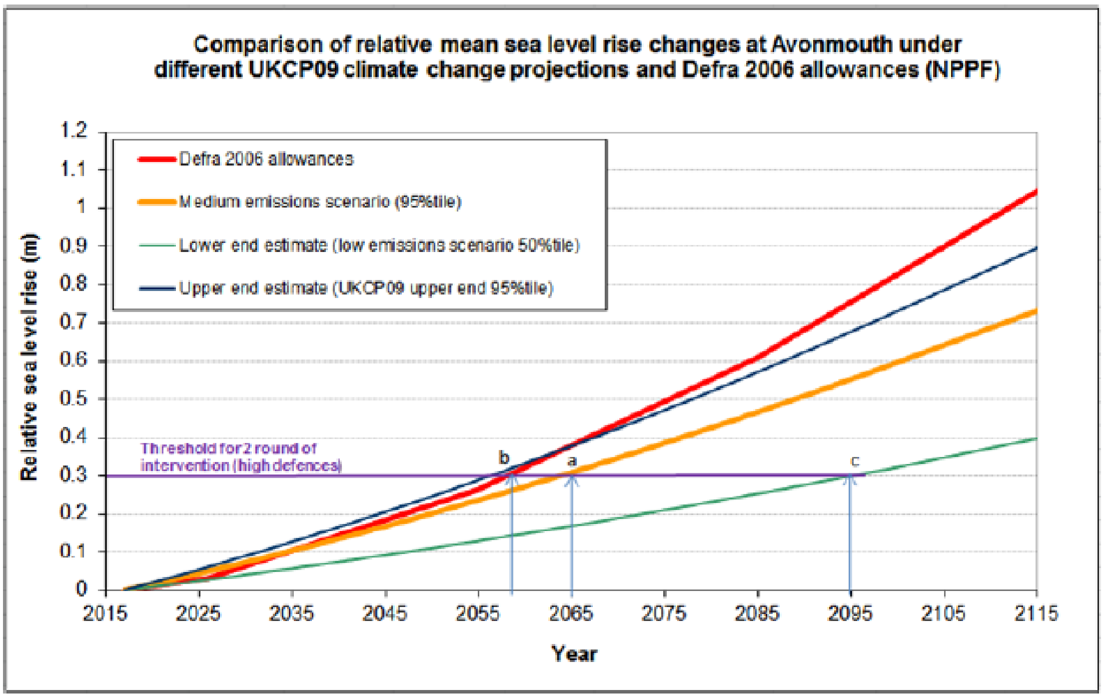


Figure 10. **Graph demonstrating sea level rise trigger thresholds for implementation of phase 3 defences. (a) is current best estimate of required implementation for phase 3, (b) is required timing if upper end estimate materialises, (c) is required timing if lower end estimate occurs.**

Development opportunities

Some of the defences outlined by the preferred option will be facilitated by development opportunities, for example, the high defences at Totterdown. In this location it is expected that by the time high defences are required that many of the existing buildings / properties along this reach will have been redeveloped or will be redeveloping.

Given that this is the case, development opportunities should also be used as a trigger for implementing high defences. For instance, if development opportunities at Totterdown were to arise prior to 2065, then BCC should ensure that high defences are incorporated into the redevelopment proposals.

The Strategy preferred option also has a number of synergies including the retaining function for highways along the New Cut. Should the Highway Authority (BCC) have aspirations to undertake highway retaining schemes prior to the proposed flood defences then this should act as a trigger to bring forward the flood defence schemes to capture the synergies between the projects.

Funding opportunities

It is anticipated that BCC will largely be reliant on external funding sources to implement the Strategy (e.g. GiA). However, should BCC secure other sources or be able to fund works themselves then this could be a trigger to implement high defences sooner than 2065. Whilst this approach may be less favourable from an FCERM perspective (i.e. constructing high defences sooner is less adaptive), political leaders within BCC may wish to pursue the high defences sooner.

3.9.4 *Outline design*

Engineering designs for defences were developed further to improve deliverability confidence and enable a more robust cost estimate to be prepared. Value engineering of the solutions was used to drive down costs. The designs were produced to the outline design stage as far as possible and consistent with the available information; however, some key information was unavailable which limited the level of detail. Additional development and refinement of the designs will be required when developing an OBC for any of the schemes that follow on from the Strategy, and to bring them to a state suitable for a planning application.

The designs consider the defence level, alignment and the structural form of the defences to be implemented. For details of the design assumptions and methodology refer to the Preferred Option Development Report.

Defence crest levels

Table 26 details defence crest levels. The crest levels achieve a 1:200 year (0.5% AEP) standard of protection for low defences in 2030, and for high defences in 2115. The crest levels include an additional 0.2m allowance to address uncertainty. The levels increase slightly moving upstream along the New Cut, matching the increase in tidal levels.

Table 26. Defence crest levels (including 0.2m freeboard). Levels presented to m AOD

Defence section	Modelled water level (2030)	Modelled water level 2115	Low defence crest level - 2030 1:200 year standard (0.5% AEP))	High defence crest level - 2115 1:200 year standard (0.5% AEP)
Entrance Lock	9.45	10.10	9.65	10.30
Cumberland Road	9.45	10.10	9.65	10.30
Cumberland Road underpass	9.45	10.10	9.65	10.30
Commercial Road and Bathurst Dam	9.45	10.10	9.65	10.30
Clarence Road	9.45	10.10	9.65	10.30
Cattle Market Road	9.60	10.20	9.80	10.40
Totterdown / St. Phillips	9.60	10.20	9.80	10.40
Netham	9.60	10.20	9.80	10.40

Defence alignments

The defence alignments maximise benefits to property and transport infrastructure as well as amenity assets, whilst minimalizing impact on flood storage and flow capacity of the River Avon.

Detailed maps of the alignment at each defence section are found in Appendix C.

Table 27 details the height of the proposed defences above existing ground levels. The height varies depending on local topographic conditions. For low defences, the average height of defence sections ranges from 0.7 to 1.1m. For high defences, the total average height ranges from 1.4 to 1.8m.

Defence structure type

Reinforced concrete cantilever walls have generally been proposed for defences less than 2m in height. Sheet piled walls have generally been proposed for defences over 2m in height, for locations where it is necessary for the defence structures to retain the land behind as well as act as a tidal defence (e.g. Clarence Road) and where topography means a cantilever wall may not be feasible. In the great majority of cases, low defences are designed such that the subsequent raising in 2065 can be achieved without any works to their foundations.

Table 27. Summary of defence section types, length and heights above current ground levels

Defence section	Structure type(s)	Defence length for low defences (km)	Defence length for high defences (km)	Average height for low defences (m)	Average height for high defences (m)
Entrance Lock	Floodwalls, flood / lock gate replacement, highway / bridge abutments, ramps, road raising	0.9	0.9	1.1	1.8
Cumberland Road	Floodwalls	0.6	0.6	0.8	1.5
Cumberland Road underpass	Floodgate, ramp and floodwall tie-ins	< 0.1	< 0.1	1.1	1.7
Bathurst Dam	Raising of existing structure, tie-in walls	< 0.1	< 0.1	0.7	1.4
Commercial Road	Floodwalls and retaining structure at Commercial Road	0.2	0.3	0.7	1.4
Clarence Road	Floodwalls, retaining structure and bridge abutment	0.6	0.6	1.0	1.6
Cattle Market Road	Floodwalls, retaining structure	0.2	0.2	0.8	1.4
Totterdown / St. Phillips	Floodwalls, ramps, resilience structures to existing buildings, bridge abutment	1.5	1.5	0.9	1.4
Netham	Floodwalls, flood / lock gate replacement, road raising	0.7	0.7	1.0	1.6
Additional works to prevent adverse impacts	Raising of embankments, sheet piles and PLP	1.5		Varies between areas	

3.9.5 *Economic assessment*

Average benefit cost ratio

The preferred option costs and benefits were refined during the additional work. Present value whole life costs for the option reduced from £166m to £67m mainly due to the phased delivery of the defences (i.e. by delaying the New Cut defences until epoch 2), refinement of design assumptions and updated costing. The economic benefits of the preferred option also reduce if the defences are phased, falling from £1,576m to £1,531m.

As a result of the economic updates, the ABCR of the preferred option increases from 9:1 to 23:1. This is shown in Table 28 below.

Table 28. Updated preferred option costs and benefits

Option	Notes	PV costs (£m)	PV benefits (£m)	ABCR
Preferred option prior to updates	Original capital cost estimates and phasing (all low defences in epoch 1)	166	1,576	9:1
Preferred option following updates*	Updated capital cost estimates and phasing (New Cut low defences delayed until epoch 2)	67	1,531	23:1

*note that the preferred option following updates is for central Bristol only. Costs for Pill and Shirehampton are excluded (amounting to approximately £30m capital cash cost).

Incremental benefit cost ratio

Prior to the update the incremental benefit cost ratio of the preferred option relative to the Do Minimum scenario was approximately 1.8. Following the reduction in costs and benefits the IBCR of the preferred option relative to the Do Minimum scenario is approximately 3.5. This positive IBCR further justifies the choice of this option.

As part of the additional work, costs were updated for the preferred option only, and no cost updates were made to the other short list options as the preferred option decision process was not revisited. Nonetheless, inspection of the additional costing work that has been undertaken shows that if the short list option costs were to be updated, the cost reductions for the other raised defence options would be similar, leading to a similar conclusion on preferred option.

3.9.6 *New Cut Greenway*

Whilst the Strategy is currently recommending a fundable and deliverable preferred option, the city and partners have aspirations to deliver more. The landscape and visual appeal within central Bristol is integral to the character of the city and the objectives of BCC. Work has been undertaken to establish how to incorporate landscaping opportunities in the proposed defence schemes.

The pressing need to provide flood defences along the River Avon creates the opportunity to carry out transport and public realm improvements. The New Cut Greenway initiative is a once in a generation opportunity to reshape, repair and reconnect the city to the River Avon and to promote travel by foot and bike, improving safety, making accessible places, and maximising development potential. It will ensure the flood investment also delivers essential transport and housing outcomes for the city and wider region.

The New Cut Greenway proposals would maximise the positive local and regional impact of the Strategy proposals to construct tidal flood risk management infrastructure along the length of the New Cut from Netham Lock Junction to Cumberland Basin. The Greenway will look to regenerate and enhance the riverside environment and provide a high quality, legible link along the river corridor (Figure 11).

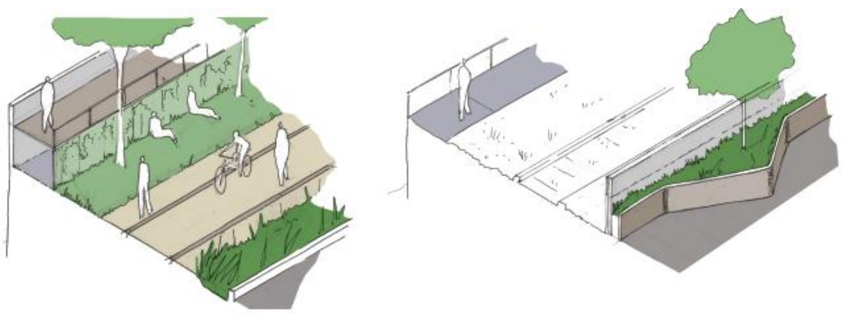


Figure 11. Sketches showing indicative potential opportunities for the New Cut Greenway incorporating the linear flood defence infrastructure.

The 'Green way' proposal will be beneficial to the city and will create a better, healthier, safer, more sustainable and prosperous city in which people can thrive by planning a city where neighbourhoods are not isolated but interconnected so that varied social, economic and cultural opportunities are easier to access by all. Other cities divided by rivers have successfully seized similar opportunities and used them to regenerate more disadvantaged areas such as Belfast, Derby, Dublin, Glasgow and Sheffield.

The Greenway will achieve this by integrating infrastructure improvements along the corridor that will encourage growth, enable the delivery of housing, improve the resilience of Bristol's transport network and city infrastructure through improved flood defences and support inclusive growth for healthy and sustainable communities.

The Greenway will compliment recent investments along the length of the New Cut, including MetroBus and RIF-funded transport schemes. The Temple Quarter Enterprise Zone occupies circa 100 hectares midway along the New Cut Greenway with Temple Meads railway station at its core. The project will therefore also enhance deliverability and wider impacts of adjacent development opportunities including the Temple Quarter Enterprise Zone.

The Greenway corridor is shown in **Figure 12** below.

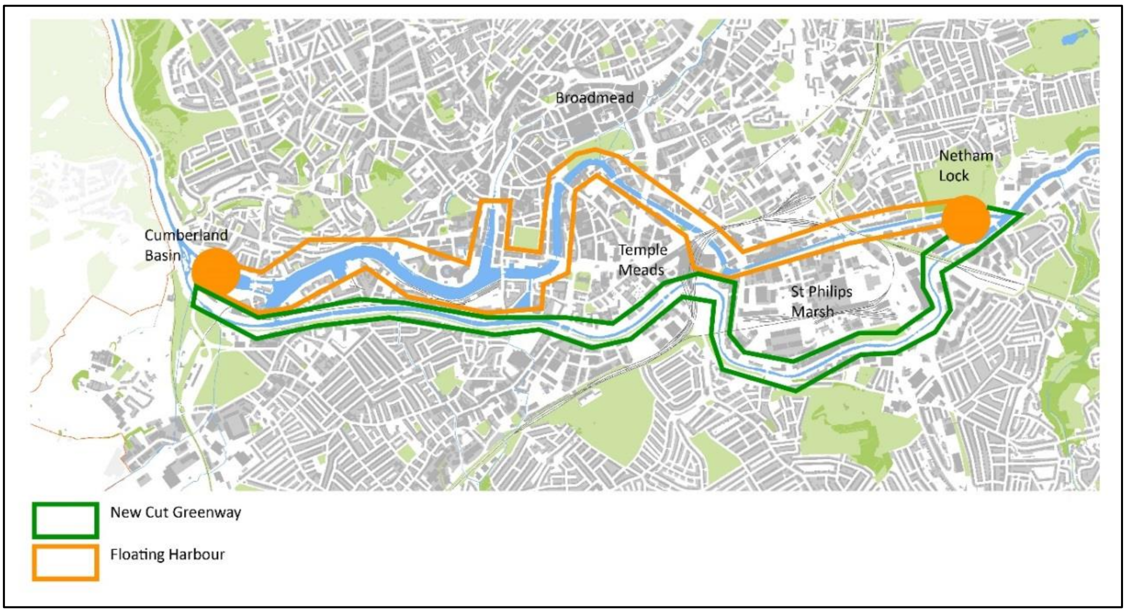


Figure 12. **New Cut Greenway location.**

The New Cut Greenway proposals will provide amenity and ecological benefits and strongly contribute towards a green infrastructure strategy for the 'greenway'.

At this early stage, a number of concepts have been generated for the greenway and how best to incorporate the proposed flood defences into the landscape (see Appendix F). For the concepts, various locations have been selected, but the ideas and concepts are not confined to any one location and can be adapted to the various interventions. In developing the concepts it is assumed that consultation / engagement will be undertaken to ensure the proposals meet the needs and objectives of the different stakeholders.

For more information on the Greenway proposals, refer to the Greenway Concept Sketches delivered as part of the Strategy.

It is recognised by BCC that additional funding for the New Cut Greenway will be required and this element of work will not be funded by GiA. The costs associated with the Greenway have not yet been developed and will be explored during work following the Strategy.

3.9.7 *Residual risk*

Residual risk for the Strategy has two main elements: risks associated with failure of the defences and risks associated with events occurring which exceed the design parameters of the defences.

During the Strategy a number of model runs to investigate residual risk have been undertaken. These include runs to investigate the residual risk associated with defence breaches at numerous locations along the raised defence alignments and also at the entrance points to the Floating Harbour. In addition, a model run to investigate the impacts relating to sea level rise and above design standard flood events has also been undertaken. Detailed descriptions of these modelling results can be found in the Additional Modelling report and Preferred Option Development Phase report.

Flood risk is currently a threat to existing property and a 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. Once implemented, the Strategy will provide the nationally prescribed standard of protection required for new development to proceed. Protection from the potential threat posed by residual flooding will be afforded by the provision of site specific mitigation/evacuation measures.

Flood risk associated with defences failing

A full description of the additional modelling undertaken to establish the flood risk should the defences fail is found in the Additional Modelling report. In summary, for the worst case design event, the flood risk during a 2115 200yr event (0.5% AEP) with Entrance Lock gates failing, leads to flooding in areas around Entrance Lock, Junction Lock, Victoria Street, Temple Black and at St. Phillips. However, for this scenario the existing gates at Junction Lock remain operational (closed) which significantly reduces the flood risk compared to a scenario when both Entrance Lock and Junction Lock gates would both be open (considered to be extremely unlikely and not a realistic situation).

Failure of the proposed gates at Netham shows that during a 2115 1:200 year event (0.5% AEP) flooding occurs around Netham and St. Phillips but flood depths in some areas are reduced compared to the Do Minimum scenario. This is because defences along the River Avon and Netham prevent overtopping and with Entrance Lock gates closed and raised, there is more storage capacity within the Floating Harbour.

The flood risk associated with breaching of the raised defences has been modelled extensively and the results are discussed in the Additional Modelling report.

Strategy - Minimising Residual Risk

When the preferred option is in place the chance of failure by breaching / failing open will be minimal compared to the present day. At the downstream entry to the harbour the preferred option will ensure that there are two sets of gates; new gates at Entrance Lock and the existing gates at Junction Lock. Even if the new gates were to breach / fail open then the existing gates at Junction Lock would be closed to block the most direct pathway for water to flow into the Floating Harbour. Some overtopping / outflanking of the Junction Lock gates would occur during significant events but the volume of water entering the harbour would be considerably reduced compared to an open channel.

In addition to the above, the new flood / lock gates at Entrance Lock and Netham will be constructed with multiple levels of redundancy to the power supply and operation to reduce the chance of failure. There are also last resort means of protection which could be implemented in order to reduce the time period of exposure should a failure occur. For example, at Entrance Lock and Netham a stop-log type system could be deployed or sand-filled bags could be stored on site and placed in the channel during a failure.

It should be noted that the likelihood of failure of the new walls will be extremely low as:

- they will be constructed as ‘hard defences’ (concrete walls or sheet piles) generally not susceptible to failure in the way that ‘soft’ defences (earthen banks) may be; and
- they will be designed to accommodate loadings from the design water levels plus a 200mm allowance (freeboard) for dealing with uncertainty . The foundations of the walls will be designed for 1:200yr (0.5% AEP) water levels at 2115 plus the freeboard allowance. In practice this means the foundations are designed structurally for a standard exceeding 1:200yr (0.5% AEP) over the full 100 year lifetime.

In the design of the raised defences passive defence has been preferred wherever possible. This includes ramps or ground raising to maintain access across defence alignments rather than installing temporary floodgates. However, in some locations manually operated defences have been identified as the only feasible way of maintaining access, for example at Entrance Lock, Cumberland Road underpass and Totterdown / St. Phillips.

The use of manually operated gates increases the residual risk of defence failure as there is a change that the gates could be left open during flood events. In the event of a temporarily deployed flood gate being left open the flow pathway through the defences would be limited and the amount of flooding that would be expected to occur is significantly less than a breach at Entrance Lock or Netham. The flood risk associated with the manually operated gates being left open has been modelled and the results are described in the Additional Modelling report. It is recommended that the current operational protocols are extended and refined to ensure that BCC have a team to operate and close the flood gates during events.

Flood risk associated with above design events

A description of the flood risk associated with above design standard flood events is provided in the Additional Modelling Report. The level of risk from these events varies across the city but it should be recognised that the Strategy is unable to completely protect the city from flooding. Irrespective of the standard of protection provided, there will always be the potential for events which exceed the crest level of the defences and cause flooding. For instance, even if defences are constructed to a 1:1000 year SoP, there is still a risk of a 1:2000 year (0.05% AEP) event occurring (albeit, very small).

It is expected that in the update of the Local Plan, provision will be made for the Strategy to be designated as evidence in the assessment of flood risk, and that site specific flood risk assessments will be required to determine what measures are required in conjunction with the strategic defences to reduce flood risk to an appropriate level.

3.9.8 ***Fluvial flood risk***

The preferred option will produce benefits against fluvial flood risk however this has not been quantified and therefore hasn't been included in the economic assessment. Numerical modelling of a selection of fluvial return period events has been undertaken and suggests that the preferred option will not make the fluvial flood risk any worse compared to the Do Minimum scenario:

- The results associated with the 1 in 20 year fluvial event (present day) with the preferred option in place are very similar to the equivalent event under a Do Minimum scenario.
- The results associated with the 1 in 75yr fluvial event (present day) preferred option scenario are very similar to the equivalent event under the Do Minimum scenario.
- The only significant difference between the preferred option and Do Minimum results for the 1 in 200 year fluvial event (2030 and 2065) is at Feeder Canal. During the Do Minimum there are no defences along the River Avon and therefore water overtops slightly earlier when compared with the preferred option scenario, and flood depths and slightly greater.

3.9.9 ***Environmental compliance***

Environmental assessment has formed one of several work streams informing the development of the Strategy in order to ensure that environmental constraints and opportunities have been integrated throughout the project. A number of environmental reports have been produced to demonstrate the environmental compliance of the preferred option for the Strategy, including:

Strategic Environmental Assessment (SEA)

An 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 found that although all of the options have a potential for significant adverse impacts on quality of life and natural and built environments, both temporary and permanently, there is also a potential to mitigate these impacts and an opportunity to provide enhancement as part of the design of all options.

The SEA found likely significant effects to the following environmental topics:

- Biodiversity (negative);
- Health/Population/Material Assets (positive); and
- Cultural Heritage (positive)

Similarly, minor effects were identified for:

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

A number of methods / actions have been identified to mitigate potential negative effects and these are presented in the SEA Environmental Report.

Habitat Regulations Assessment (HRA)

A preliminary HRA report has been carried out which presents an analysis of the Likely Significant Effects of the Strategy on the European sites for which a risk of effect is present; the Severn Estuary SAC and Severn Estuary Ramsar site, with specific reference to their migratory fish qualifying interests. The preliminary report concluded that the Strategy would result in “no likely significant effects” on any European Sites, either alone or in combination with other projects and plans, providing a number of precautionary measures are followed such as; using low noise and vibration piling techniques and carrying out works outside of the sensitive season for fish migration.

The conclusion will be reviewed in the HRA, which would be dealt with under the EIA process, once the precautionary measures have been further developed and incorporated into the project, in order to confirm the conclusion of no likely significant effects.

Water Framework Directive (WFD)

An Outline Preliminary WFD Assessment has been carried out which has confirmed the need for a WFD assessment on the basis that the defences in some locations will be constructed in currently undefended areas. This may have a negative impact on the ecological potential for the waterbody (Bristol Avon). The reason for this is that constructing defences in currently undefended areas will likely involve a reducing of aquatic habitat area; there is also the potential for the hydromorphology of the waterbody to be negatively affected. The aim of the WFD assessment will be to evaluate the total combined length and percentage of the water body affected to assess the overall significance of this impact. Whilst an individual scheme may have an insignificant impact on WFD quality elements with a reach, the combined effect of several small-scale schemes may cause deterioration to the ecological potential of the waterbody.

Environmental Impact Assessment (EIA) pre-scoping

An EIA pre-scoping report has been produced 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.

Summary of Key Benefits of the Strategy:

Future Proofing - nearly 3700 properties better protected against flood risk in Central Bristol over the next 100 years.

Adaptive – mitigates climate change and sea level rise with sufficient flexibility to adapt to the range of future scenarios and thereby maximising return on investment.

Catalyst - supports economic prosperity and Bristol’s development and regeneration aspirations.

Broader Outcomes - potential to deliver public realm and access improvement through linkage and delivery of New Cut Greenway plans.

Environment – the delivery of the strategy provides opportunities for environmental enhancement (e.g. native planting, urban greening etc.)

4. THE COMMERCIAL CASE

4.1 Introduction and procurement strategy

Procurement for the Strategy schemes will first involve the OBC and then the detailed design, associated surveys and investigations, construction and supporting specialist advice and expertise required to successfully manage and deliver a major capital project. It is likely that the procurement approach for detailed design and construction will be decided during or after the OBC stage, but for information the different approaches are outlined below.

The key criteria for the scheme procurement include:

- time (speed or certainty of completion date)
- cost (price level or cost certainty)
- quality (functionality and performance)

The most suitable procurement strategy is largely dependent on the priority assigned to each of these and for construction could include a traditional design-bid-build or a specialist design and build (D&B) contract. An overview of these different procurement approaches is provided in Table 29.

Table 29. Overview of the different procurement approaches

Approach	Good for:	Not suited for:
Traditional (design-bid-build)	- Quality; full design pre tender - Design flexibility, variations and instructions - Specialist subcontractors - Design control - Cost; there may be a lump sum cost benefit unless multiple changes are made	- Time; require full detailed pack pre tender - Cost; not a benefit if many changes are made
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; in employee requirements	- Quality; cheapest route to meet contract specification can lead to low quality products / build quality - Design flexibility; request for changes will have cost / time implications

Procurement of any services and works associated with delivery of the schemes will follow BCC contract procedure rules to ensure compliance with relevant legislation.

4.2 Key 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.

4.3 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:

- Water and Environment Management Framework (WEM framework)
- Scape Procure – Civil Engineering and Infrastructure Framework (Scape Framework)
- BCC Flood risk Consultancy Framework
- Bespoke tender

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

- Autumn 2017 – Tidal Strategy finalised
- Autumn 2017 to Autumn 2018 – Wider integration opportunities (i.e. New Cut Greenway, Harbour Asset Management Strategy). Completion of integrated Strategy
- Spring 2019 – Strategy approval
- Spring 2019 to Spring 2021 - Outline Business Case and Secure Funding
- Spring 2021 to Autumn 2022 – Detailed Design, Full Business Case and Phase 1 Consenting
- 2023-2025 – Phase 1 delivery underway

4.4 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). Efficiencies will be explored at the OBC stage.

5. THE FINANCIAL CASE

5.1 Financial summary

Table 30 provides a breakdown of the Strategy costs per epoch. Costs are provided in cash and present value terms.

In the table the capital costs refer to the construction and preliminary costs associated with building the new defences. Maintenance costs refer to the costs associated with maintaining the defences whilst ‘Other’ costs are those costs associated with Floating Harbour operation and maintenance that is specific to managing the flood risk (i.e. deployment and upkeep of stop gates). The average annual non-discounted (cash) costs for these activities differs between time epochs due to the implementation of schemes.

Table 30 **Financial breakdown of the Strategy costs**

Epoch	**Non discounted cash cost (£k) including 60% optimism bias**				**Present value cost (£k) including 60% optimism bias**			
	Capital	**Maintenance**	**Other**	**Total**	**Capital**	**Maintenance**	**Other**	**Total**
Epoch 1	43,300	650	550	44,500	43,300	510	430	44,240
Epoch 2	18,440	5,290	1,490	25,220	11,000	1,990	550	13,540
Epoch 3	44,240	6,030	5,130	55,400	8,730	680	490	9,890
			Total	125,120			**Total**	67,680

5.2 Partnership funding scores

5.2.1 Scheme breakdown

Partnership Funding is the measure by which the Environment Agency determines the amount of Grant in Aid (GiA) funding appropriate for a flood defence scheme, and the priority of that scheme within the Agency’s programme of works.

Partnership funding scores have been developed for the Strategy works which would be implemented in 2015 and 2030, using the costs, benefits and outcomes (e.g. numbers of properties removed from specific flood risk bands) of those works.

To derive the partnership funding scores the works have been grouped into a 2015 scheme and a 2030 scheme.

The 2015 scheme includes works to Floating Harbour defences - Entrance Lock, Cumberland Road underpass, Bathurst Dam and Netham - and the works to Totterdown / St. Phillips.

Costs for the additional works which are required to prevent adverse flood impacts elsewhere - Ashton Bower, Netham and Bedminster - have been included in the costs for the 2015 scheme to ensure all mitigation is in place at the outset of the Strategy.

The 2030 scheme includes the works to The New Cut defences - Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road.

Where BCC elects to proceed with measures intended to enhance the area but which are not strictly required for flood defence – such as landscaping and amenity works identified in the New Cut Greenway section of this report (section 3.9.6) – then these measures are not eligible for GiA.

5.2.2 Baseline

Environment Agency guidance recommends use of the Do Nothing scenario in the funding assessment. However the partnership funding scores are very sensitive to the assumptions within this scenario and therefore further work has been undertaken as part of the Strategy to test these sensitivities.

The key assumptions relate to the operation of the Floating Harbour tidal stop gates at Junction Lock (ordinarily open and with no navigation function) and Netham (ordinarily closed and navigation function). The Do Nothing scenario assumes these gates are not operated (and fail open) from year 0. The Do-Minimum scenario assumes that they are operated throughout the appraisal period during all return periods of flood events.

By assuming an immediate open position of the critical stop gates to the Floating Harbour it produces significant immediate tidal flood risk (compared to what is currently experienced and observed on the ground due to harbour maintenance, operations and gate deployment) and this consequently drives large monetary damages (£1.6bn PV over 100 years) as opposed to maintaining the status quo 'Do Minimum' (£316m PV over 100 years).

Assessing the partnership funding potential against the Do Nothing scenario therefore drives large monetary damages and produces a large number of OM2 properties at risk compared with the 'status quo' (Do Minimum). Given the large sensitivities due to the key gate open / closed assumption it was considered prudent for the Strategy to also establish the level of funding which could be available with an alternative 'hybrid' baseline. This work ensures that there is the necessary evidence base for the alternative PF assessment and economic case should it be required in the future and defines the range of partnership funding scores and contributions which could reasonably be expected.

The alternative 'hybrid' baseline comprises a combination of the critical gate position assumptions for Do Nothing and Do Minimum scenarios. Under this alternative baseline, gates are assumed to remain in a closed position until they reach the end of their residual life and are then assumed to fail in an open position. It is not currently possible to predict the specific point in time that this transition occurs (due to a lack of residual life information) so therefore it has been assumed to occur in 2030. For more information on the basis for this assumption refer to the *Technical Note; testing impact of an alternative baseline for potential financing* (AECOM, 2017).

Adoption of the alternative 'hybrid' baseline leads to considerably reduced economic benefits and OM2 properties at risk (compared to the Do Nothing baseline). This is mainly due to a decrease in annual average damages (AAD) accrued over epoch 1 and a delay (and therefore discounting) to the write-off of a large number of properties associated with the gates failing open.

BCC have also requested that a PF calculation was undertaken using the Do Nothing baseline as the basis for the OM1 benefits but the alternative 'hybrid' baseline as the basis for the OM2 property counts (before and after the scheme).

When describing the different baselines in the remainder of this section the following baseline labels have been adopted:

- Baseline A: Do Nothing from present day
- Baseline B: Alternative 'hybrid' baseline
- Baseline C: OM1 based on Do Nothing (A), OM2 based on alternative 'hybrid' (B)

5.2.3 Scores

Table 31 shows the partnership funding scores for the schemes. For the initial scheme, the scores considering baselines A to C have been calculated. For the second phase scheme only baseline A (Do Nothing) has been considered.

In cases where the scheme would fall below the 100% threshold, the table also provides an estimate of the cash shortfall that is required to make up the shortfall and achieve a score of 100%. Recent EA advice is that partnership funding scores should be at least 120% and therefore if the score falls below this higher threshold then the estimated funding shortfall for this score is also presented.

Table 31. Partnership funding scores

Scheme	Baseline	Base date for calculation	Capital cost of scheme	Raw PF Score	Estimated funding shortfall to achieve 100% score	Estimated level of GiA funding available should score reach 100%	Estimated funding shortfall to achieve 120% score
2015 scheme - Floating Harbour and Totterdown / St. Phillips schemes	**A: Do Nothing**	Present day	£43.3m	135%	£0	£43.3m	£0
2015 scheme - Floating Harbour and Totterdown / St. Phillips schemes	**B: Hybrid**	Present day	£43.3m	80%	£8.6m	£34.7m	£17.1m
2015 scheme - Floating Harbour and Totterdown / St. Phillips schemes	**C: OM1 Do Nothing, OM2 hybrid**	Present day	£43.3m	125%	£0	£43.3m	£0
2030 scheme - New Cut defences (Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road)	**Do Nothing**	2030	£18.4m	13%	£15.9m	£2.5m	Assume full external contribution required to fund scheme

5.2.4 Recommendations for funding

Until the appropriateness and validity of some key baseline assumptions underpinning the financial assessment are confirmed with the EA's LPRG the amount of funding which is likely to be available to the scheme is uncertain. Recommendations for the next steps and developing the funding case are provided in detail in the *Technical Note; testing impact of an alternative baseline for potential financing* (AECOM, 2017).

From the sensitivity testing (Do Nothing vs the Hybrid baseline) the PF score for the phase 1 scheme ranges between 80-135% and it seems reasonable to assume a potential range of FCERM GiA funding for the phase 1 scheme of £34 - £43m (subject to the required shortfall being met from other funding sources). Therefore, based on the current cost estimate, an anticipated 'worst case' funding shortfall of approximately £9m results.

For the purposes of financial planning, given the profile and magnitude of the phase 1 scheme it is not unreasonable to expect that a financial contribution would be required from BCC towards the scheme (even with a PF score of above 100%, as with the Do Nothing baseline). Some of this sum might be in the form of 'in kind' contributions such as associated works delivered by BCC or developers.

Where BCC elects to proceed with measures intended to enhance the area but which are not strictly required for flood defence – such as landscaping and amenity works identified in the Resilience Corridor section of this report – then these measures will need to be fully funded by BCC as they are not eligible for GiA.

The table shows that the 2030 scheme falls considerably short of a robust PF score and will definitely require significant contributions from BCC. In the course of Strategy development, a number of funding sources have been identified with the potential to meet this requirement. One of these is the Local Enterprise Partnership.

Going forward it is recommended that liaison and dialogue with the EA's LPRG or investment and funding specialist 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. At OBC stage it is recommended that the partnership funding calculations are revisited.

5.3 Impact on revenue and balance sheet

BCC will act as the accountable body for the OBC and detailed design / construction stages of the scheme development. BCC has experience of managing capital construction projects and and will be responsible for performance and compliance to ensure the activities supported fit within the programme objectives, are value for money and are an efficient use of public resources.

On completion of construction of the defences in epoch 1, anticipated to be in 2025, a series of flood risk management assets will be created. The revenue costs associated with the maintenance required over the whole life of the Strategy have been estimated and are presented in Table 30.

5.4 Overall affordability

Table 32 provides a breakdown of the capital costs of the Strategy epoch 1 schemes. The raw outcome measure score and total GiA contribution are also shown. Note that the GiA contribution presented below aligns with use of the Do Nothing baseline discussed in section 5.2.

Table 32 **Capital cost breakdown and GiA contribution**

Scheme	Defence / benefit area	Epoch 1 (Low Defences) Capital cost (£k)
Entrance Lock	Floating Harbour	14,020
Cumberland Road underpass	Floating Harbour	410
Bathurst Dam	Floating Harbour	470
Netham	Floating Harbour	10,610
Totterdown / St. Phillips	Totterdown	5,570
Mitigation for adverse impacts	4,190	
Additional costs – lump sum construction	2,880	
Additional costs – lump sum other	5,120	
Total	43,300	
Raw outcome measure score	135%	
Total GiA contribution	43,300	
Estimated BCC funding % to meet DEFRA targets	Approx. 10-15%	

The Partnership Funding calculations indicate that the Strategy will receive a substantial element of GiA funding. In particular, the 2015 scheme is above 100% (assuming the Do Nothing baseline) which in principal demonstrates its affordability should BCC decide to proceed. Despite its high score, BCC would still be expected to contribute 10-15% of the capital costs in order to meet DEFRA targets.

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 should also be noted that the costs of the Strategy do not cover any works required to the majority of existing Floating Harbour and New Cut retaining walls. Table 33 shows that although there are some synergies – such as the new gates at Entrance Lock and Netham, and the wall at Clarence Road – in general BCC will need to provide funding for these works, and to commit to doing so in any formal submission to the Environment Agency as the Strategy is dependent on these structures.

Table 33. **Strategy dependency**

Low confidence in asset condition and high impacts assets include:	Preferred Option interface	Impact
Lock gates at Entrance Lock & Netham	Replaced (relies on existing sills)	Synergy – strategy option costs align / support existing BCC maintenance requirements
Clarence Road supporting walls	2030 walls include retaining structure	
New Cut supporting walls	2030 wall replacing MetroBus flood wall	Design structurally independent from heritage Chocolate Path and railway retaining wall
Dockside and New Cut retaining banks and Ashton Brislington Assets	'2015' walls (e.g. Entrance Lock, Totterdown and Netham)	Strategy dependant on continued serviceability and BCC maintenance outside of preferred option costing
Water level management		

5.5 Other sources of funding

Additional sources of funding are discussed in detail in the Outline Funding Strategy report which concluded that:

- The Local Enterprise Partnership (LEP) Economic Development Fund (EDF) has a programme allocation of £10m. Seeking further funding from this source could be explored but given that the EDF is fully subscribed this could only be via a substitution.
- A contribution to strategic flood defences could come from the Community Infrastructure Levy (CIL) subject to reconciling with the needs of other infrastructure projects.
- 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. However, the make-up of the programme will not become clear until next year.
- 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.
- 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.
- A Local Levy contribution has recently been sought from the Wessex Regional Flood Defence Committee (WRFFC) to further the Strategy and reduce uncertainties. 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 is unknown but could become clearer when the EA 6 year capital programme is next reviewed (January 2018).

- Potential contributions from developers / landowners / beneficiaries recognising BCC's significant land ownership of the areas proposed for defence works.
- The Local Growth Fund via the Growth Deal could also be explored for a scheme coming forward to 2020/21 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.

An indicative illustration of potential funding contributions for the preferred strategic option for works in epochs 1&2 is provided in Table 34.

Table 34. Potential funding contributions

Contributor	Potential Contribution (£m)	Notes / Assumptions
LEP EDF	10	BCC borrowing to be repaid by the EDF sourced from business rate uplift. Programme level commitment pending LEP OBC acceptance.
LEP RIF	5	Payback, in line with previous successful bids
BID	TBC	Subject to successful implementation of BID
Community Groups	0	Negligible contributions forecast
Coastal Communities Fund	1	In line with previous successful application for flood defences
WRFC Local Levy	TBC	Current allocation up to 2021
CIL	7.5	Approximately £3.5m available for strategic infrastructure each year. CIL is fully committed until spring 2018, but thereafter there is no commitment
Devolution Deal	TBC	£900m fund over 30 years. Composition of programme to be confirmed.

6. THE MANAGEMENT CASE

6.1 Project management

The OBCs, detailed design and scheme construction projects will be overseen by a multi-agency Project Board comprising senior management representation from BCC, the Environment Agency and the appointed supplier(s) and will be supported by a project team led by a dedicated Project Manager.

The Project Board will provide direction and management for the project. The Project Board will be overall authority for the project and is accountable for its success or failure. The board members will have the sufficient authority to carry out their responsibility effectively. The collective responsibilities of the Project Board members include:

- Accepting and demonstrating ownership for the project.
- 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.
- 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 project deliverables are reliable, sustainable and can be maintained effectively.

The Project Manager has the authority to run the project on a day-to-day basis on behalf of the Project Board. The Project Manager's prime responsibility is to ensure that the project produces the required product to the required standard of quality and within the specified constraints of time and cost.

6.2 Communications with stakeholder engagement

Initial stakeholder engagement was undertaken at an early stage of the Strategy development. The feedback from stakeholders helped to shape the Strategy development. Further engagement with stakeholders and also with the public will be undertaken prior to the completion of the Strategy and business case submissions.

6.3 Change management

Change management control procedures will be used for the OBC and detailed design / construction phases of the schemes.

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

6.4 Benefits realisation

The realisation of benefits will be managed by BCC in their capacity as the lead organisation for delivering the Strategy schemes. All benefits will be realised when construction works have been completed. The initial epoch 1 works are currently expected to be completed by 2025 and therefore BCC will report the realisation of benefits at that time.

The Outcome Measures to be delivered by the initial epoch 1 scheme, and the year of anticipated realisation are detailed in Table 35.

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 continuation of forecasting of flood events and asset operations.

Table 35. Outcome measures resulting from the scheme

Outcome Measure (OM)	Yr 0 (2017/18)	Yr 1 (2018/19)	Yr 2 (2019/20)	Yr 3 (2020/21)	Yr 4 (2021/22)	Yr 5 (2022/23)	Yr 6 (2023/24)	Yr 7 (2024/25)
OM2a Households moved to a lower risk category	0	0	0	0	0	0	0	843
OM2b Households moved from very significant or significant risk to moderate or low risk	0	0	0	0	0	0	0	843
OM2c Households in 2b that are in the 20% most deprived areas	0	0	0	0	0	0	0	152

6.5 Risk management

The key project risks for the Strategy are summarised in section 2.7. Refer to the project risk register for more information.

The key risks associated with detailed design and construction will be established at the OBC stage.

6.5.1 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.

Considerations will be given to CDM and key H&S issues as the preferred strategy is advanced through the development of OBC's 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 (PSRA's) 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.

6.6 Contract management

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

6.7 Assurance

Project assurance for the OBC and detailed design / construction will be undertaken by the Project Board.

6.8 Post project evaluation

Upon closedown of the OBC 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.

6.9 Contingency plans

Contingency plans will be established during the OBC stage of the scheme delivery.

6.10 Next steps

The next steps for the Strategy and further work include:

- Additional refinement of the defence designs and alignments will be required when developing an OBC for any of the schemes that follow on from the Strategy.
- Liaison with Environment Agency's LPRG Assurance Group.
- Further consideration to maintenance aspects including assessment on a site by site basis.
- Further consideration of environmental mitigation measures such as landscaping, public realm improvements and compensatory habitat provision for the potential loss of intertidal habitat.
- Development of the New Cut Greenway proposals.
- 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.
- More detailed numerical modelling to investigate flow pathways between flood sub-cells during high magnitude flood events. 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. Based on the current modelling it is not possible to determine the extent or volume of water that flows between sub-cells during the large return period events. Additional modelling may help to reduce the uncertainty and to verify the defence phasing plan. For more information, refer to the Preferred Option Development report (sections 5.2 and 5.3).
- Additional numerical modelling to support quantification of additional fluvial benefits of the Strategy to help refine and optimise the economic case. Gate deployment and pre lowering of the Floating Harbour prior to large fluvial events should be also be considered as mitigation against fluvial risk.
- Interface with wider opportunities and programmes, including the Harbour Asset Management Strategy.

APPENDICES

Appendix A – Key documents

Non-Strategy key documents

- Severn Estuary Shoreline Management Plan (2010)
- Bristol Avon Catchment Flood Management Plan (2012)
- Bristol Central Area Flood Risk Assessment (CAFRA) (2010)
- First Phase Feasibility Study (2013)

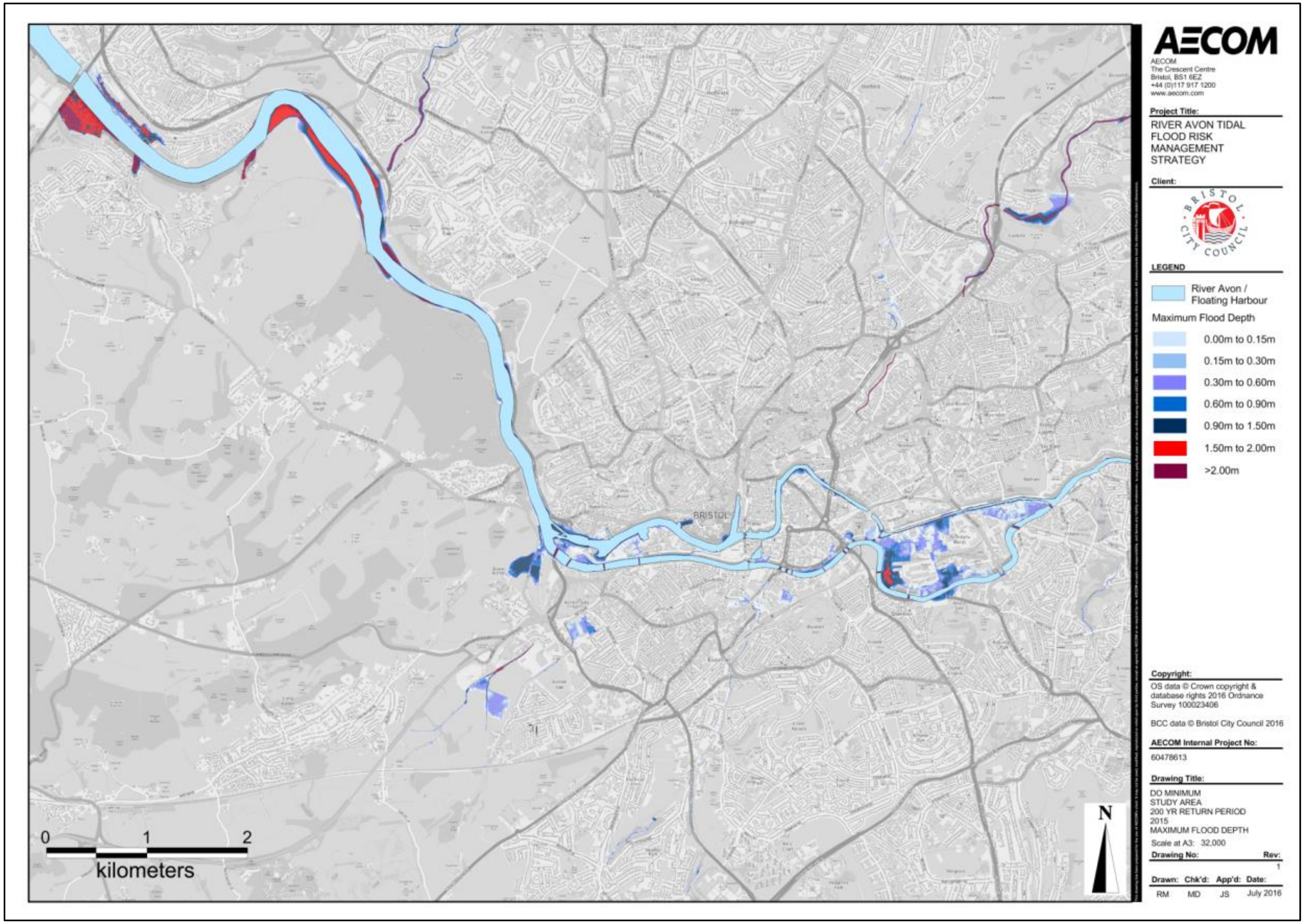
Strategy reports

- Long Listing Briefing Report
- Shortlist Report
- SEA Scoping Report
- 9B Environmental Options Report
- Economics Report (various)
- Modelling Report (various)
- Interim SEA Report
- Preferred Option Report
- Residual Risk Technical Note
- Funding Strategy
- Outline Design Report
- Preferred Option Development Report
- SEA Report

Appendix B – Flood risk mapping

The following figures show the flood depths and extent for :

- Do Minimum 2015 1:200 year event (0.5% AEP)
- Do Minimum 2115 1:200 year event (0.5% AEP)
- Do Nothing 2015 1:200 year event (0.5% AEP)
- Do Nothing 2115 1:200 year event (0.5% AEP)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BRISTOL CITY COUNCIL
LEGEND
River Avon / Floating Harbour
Maximum Flood Depth
0.00m to 0.15m
0.15m to 0.30m
0.30m to 0.60m
0.60m to 0.90m
0.90m to 1.50m
1.50m to 2.00m
>2.00m
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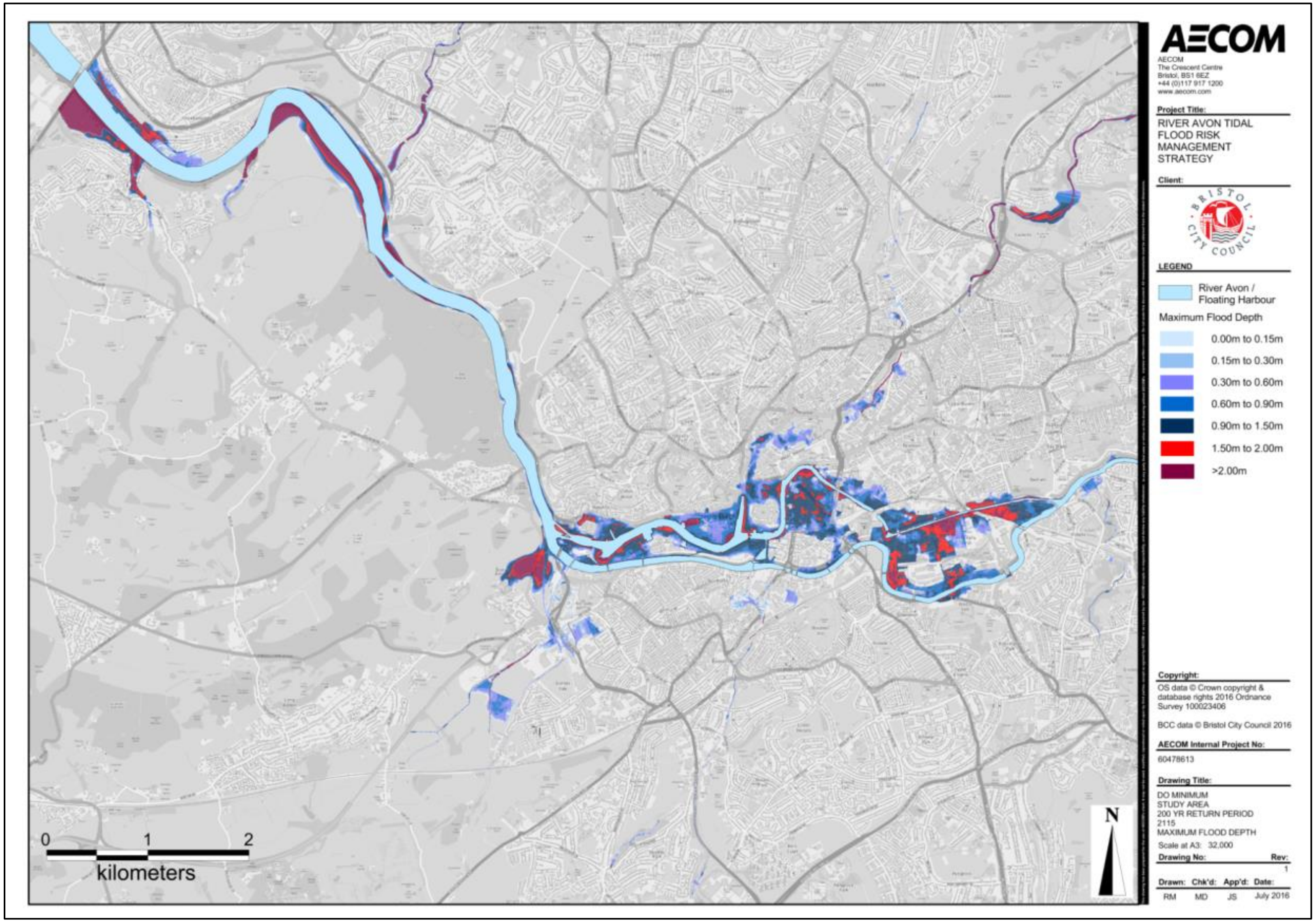
STUDY AREA
200 YR RETURN PERIOD
2015
MAXIMUM FLOOD DEPTH
Scale at A3: 32,000
Drawing No:
Rev:
1
Drawn: Chk'd: App'd: Date:
RM MD JS July 2016
BRISTOL
N
0 1 2
kilometers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RIVER AVON TIDAL
FLOOD RISK
MANAGEMENT
STRATEGY
Client:
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LEGEND
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Maximum Flood Depth
0.00m to 0.15m
0.15m to 0.30m
0.30m to 0.60m
0.60m to 0.90m
0.90m to 1.50m
1.50m to 2.00m
>2.00m
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STUDY AREA
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2115
MAXIMUM FLOOD DEPTH
Scale at A3: 32,000
Drawing No:
Rev:
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Drawn: Chk'd: App'd: Date:
RM MD JS July 2016
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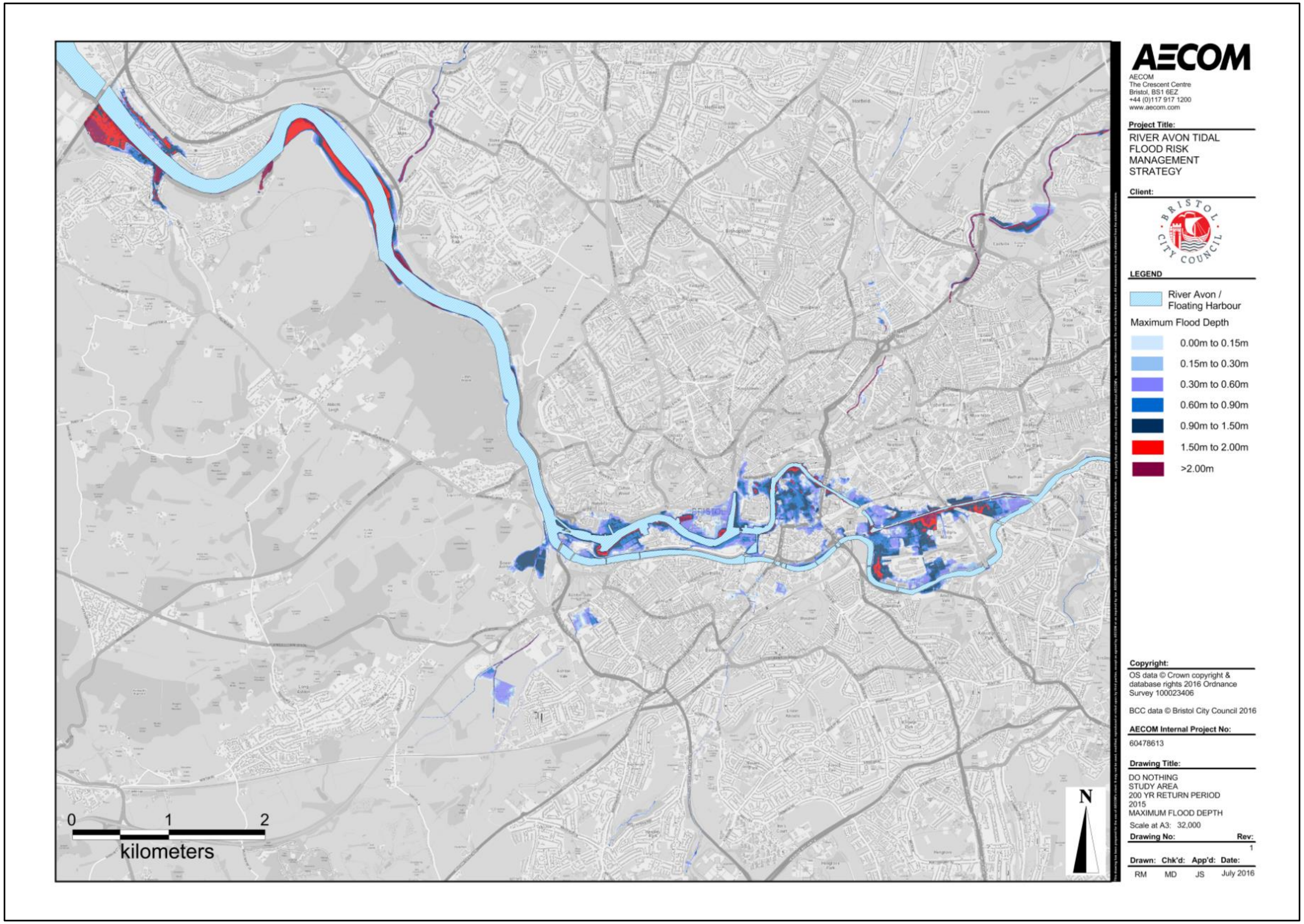
1
2
kilometers



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Project Title:
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0.90m to 1.50m
1.50m to 2.00m
>2.00m
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Drawing No:
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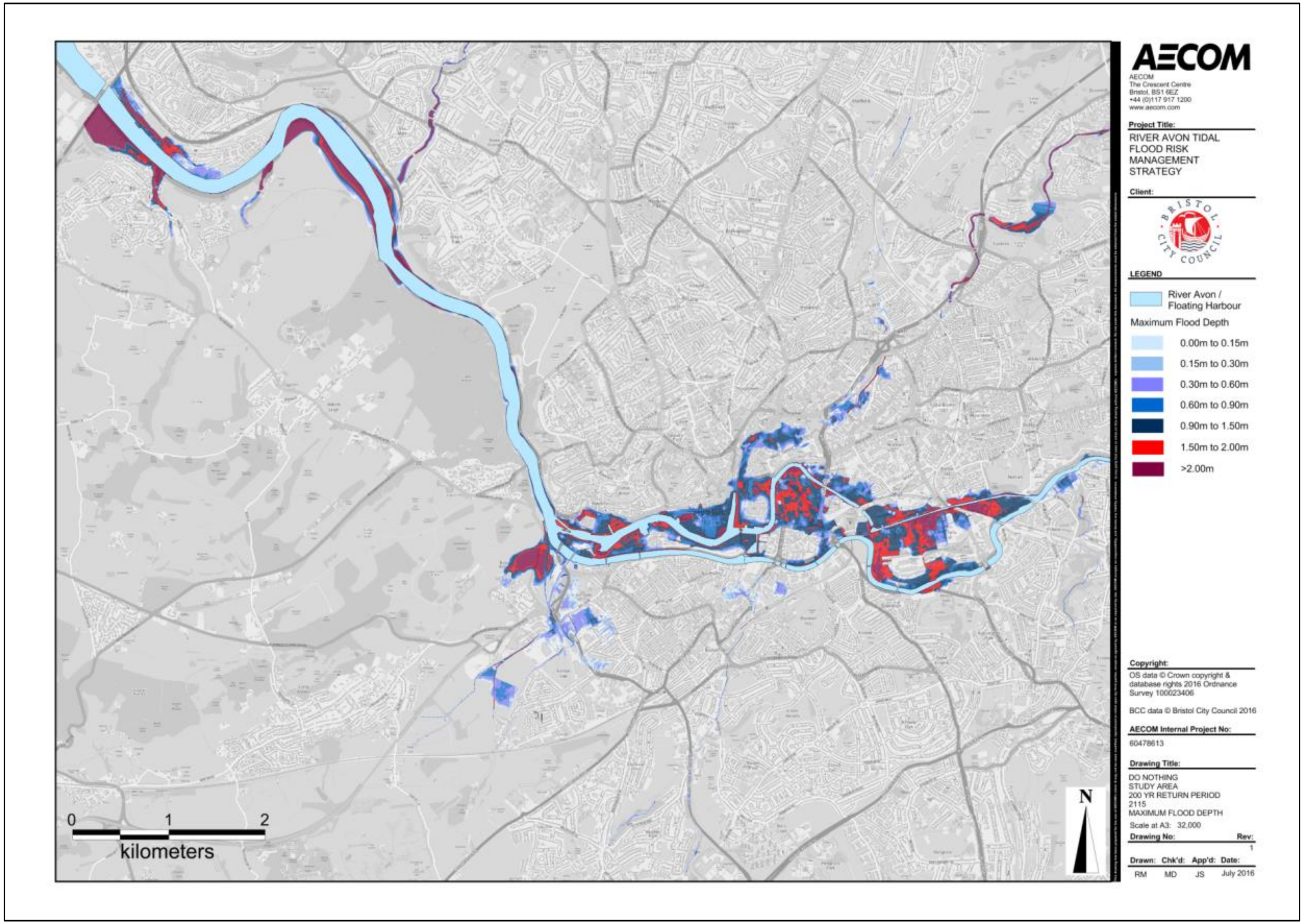
kilometers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1
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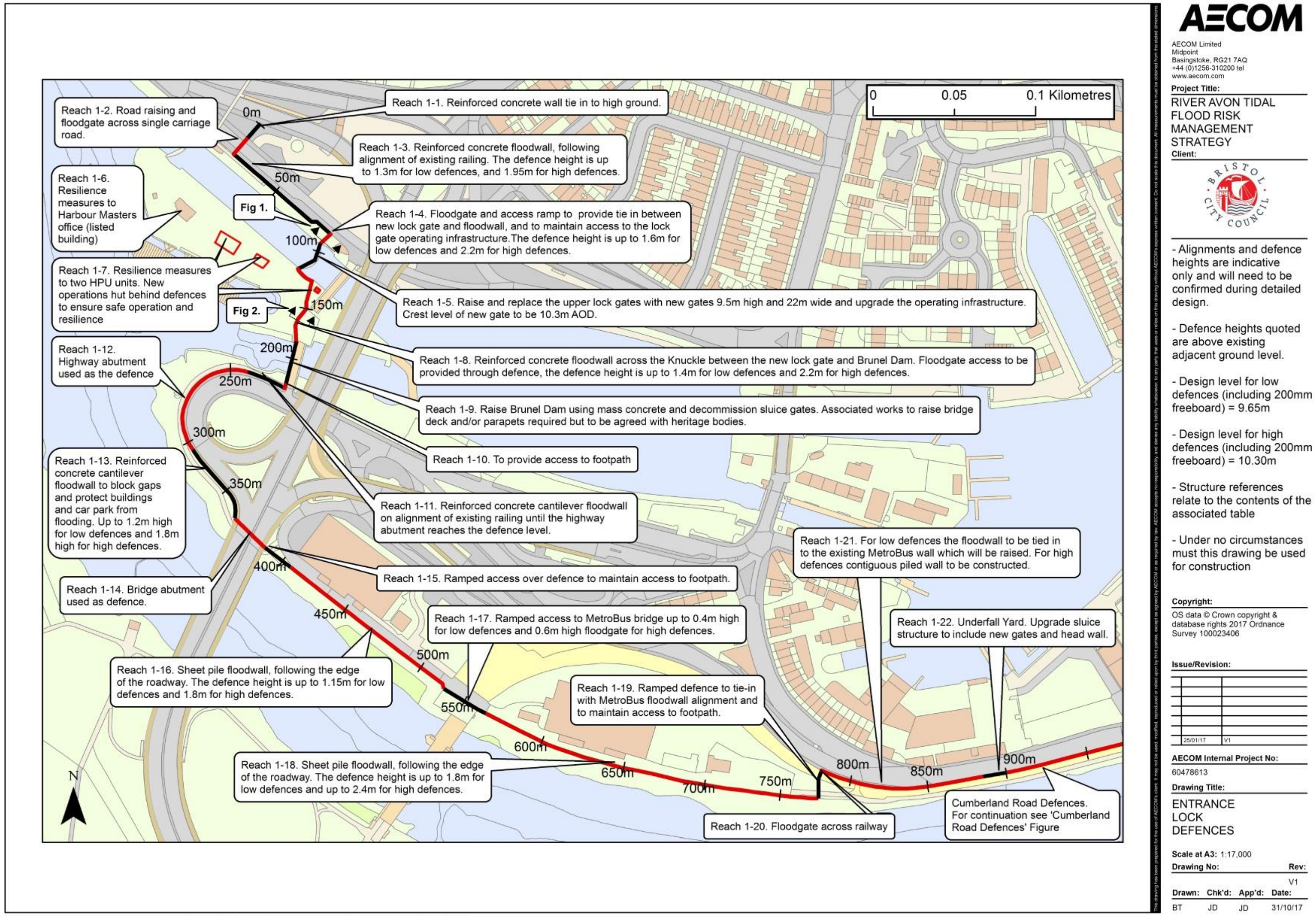
N
0 1 2
kilometers

Appendix C – Defence alignments



Reach 1-2. Road raising and floodgate across single carriage road.
0m
Reach 1-1. Reinforced concrete wall tie in to high ground.
0 0.05 0.1 Kilometres
Reach 1-3. Reinforced concrete floodwall, following alignment of existing railing. The defence height is up to 1.3m for low defences, and 1.95m for high defences.
Reach 1-6. Resilience measures to Harbour Masters office (listed building)
50m
Fig 1.
Reach 1-4. Floodgate and access ramp to provide tie in between new lock gate and floodwall, and to maintain access to the lock gate operating infrastructure.The defence height is up to 1.6m for low defences and 2.2m for high defences.
100m
Reach 1-7. Resilience measures to two HPU units. New operations hut behind defences to ensure safe operation and resilience
Fig 2.
150m
Reach 1-5. Raise and replace the upper lock gates with new gates 9.5m high and 22m wide and upgrade the operating infrastructure. Crest level of new gate to be 10.3m AOD.
Reach 1-12. Highway abutment used as the defence
200m
250m
Reach 1-8. Reinforced concrete floodwall across the Knuckle between the new lock gate and Brunel Dam. Floodgate access to be provided through defence, the defence height is up to 1.4m for low defences and 2.2m for high defences.
Reach 1-9. Raise Brunel Dam using mass concrete and decommission sluice gates. Associated works to raise bridge deck and/or parapets required but to be agreed with heritage bodies.
300m
Reach 1-10. To provide access to footpath
Reach 1-13. Reinforced concrete cantilever floodwall to block gaps and protect buildings and car park from flooding. Up to 1.2m high for low defences and 1.8m high for high defences.
350m
Reach 1-11. Reinforced concrete cantilever floodwall on alignment of existing railing until the highway abutment reaches the defence level.
Reach 1-21. For low defences the floodwall to be tied in to the existing MetroBus wall which will be raised. For high defences contiguous piled wall to be constructed.
400m
Reach 1-15. Ramped access over defence to maintain access to footpath.
Reach 1-14. Bridge abutment used as defence.
450m
Reach 1-17. Ramped access to MetroBus bridge up to 0.4m high for low defences and 0.6m high floodgate for high defences.
Reach 1-22. Underfall Yard. Upgrade sluice structure to include new gates and head wall.
500m
Reach 1-16. Sheet pile floodwall, following the edge of the roadway. The defence height is up to 1.15m for low defences and 1.8m for high defences.
550m
Reach 1-19. Ramped defence to tie-in with MetroBus floodwall alignment and to maintain access to footpath.
600m
N
Reach 1-18. Sheet pile floodwall, following the edge of the roadway. The defence height is up to 1.8m for low defences and up to 2.4m for high defences.
650m
700m
750m
800m
850m
900m
Reach 1-20. Floodgate across railway
Cumberland Road Defences. For continuation see 'Cumberland Road Defences' Figure
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ENTRANCE LOCK DEFENCES
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Drawn: Chk'd: App'd: Date:
BT JD JD 31/10/17
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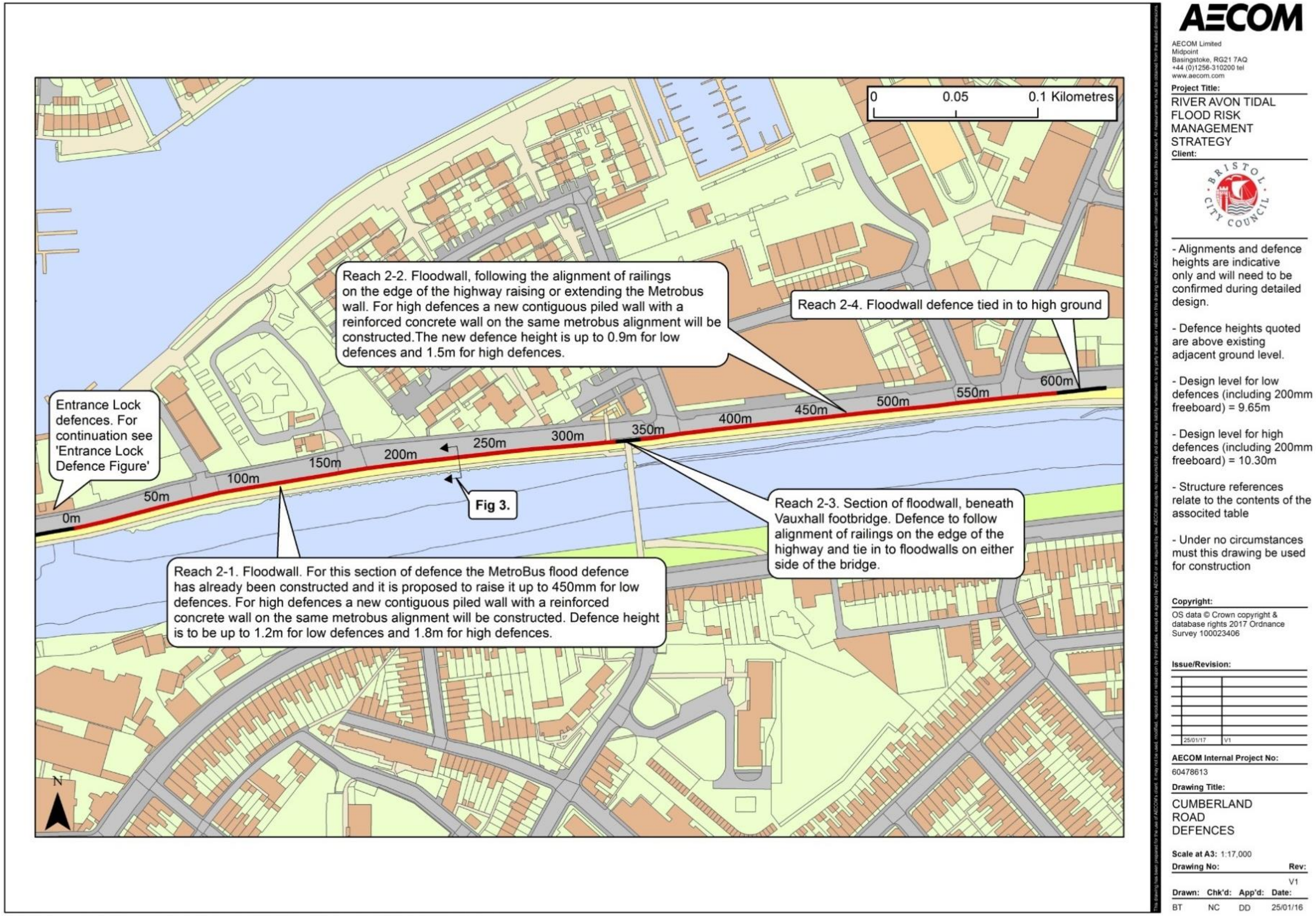

0 0.05 0.1 Kilometres
Reach 2-2. Floodwall, following the alignment of railings on the edge of the highway raising or extending the Metrobus wall. For high defences a new contiguous piled wall with a reinforced concrete wall on the same metrobus alignment will be constructed.The new defence height is up to 0.9m for low defences and 1.5m for high defences.
Reach 2-4. Floodwall defence tied in to high ground
Entrance Lock defences. For continuation see 'Entrance Lock Defence Figure'
0m
50m
100m
150m
200m
250m
300m
350m
400m
450m
500m
550m
600m
Fig 3.
Reach 2-3. Section of floodwall, beneath Vauxhall footbridge. Defence to follow alignment of railings on the edge of the highway and tie in to floodwalls on either side of the bridge.
Reach 2-1. Floodwall. For this section of defence the MetroBus flood defence has already been constructed and it is proposed to raise it up to 450mm for low defences. For high defences a new contiguous piled wall with a reinforced concrete wall on the same metrobus alignment will be constructed. Defence height is to be up to 1.2m for low defences and 1.8m for high defences.
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CUMBERLAND ROAD DEFENCES
Scale at A3: 1:17,000
Drawing No: Rev:
V1
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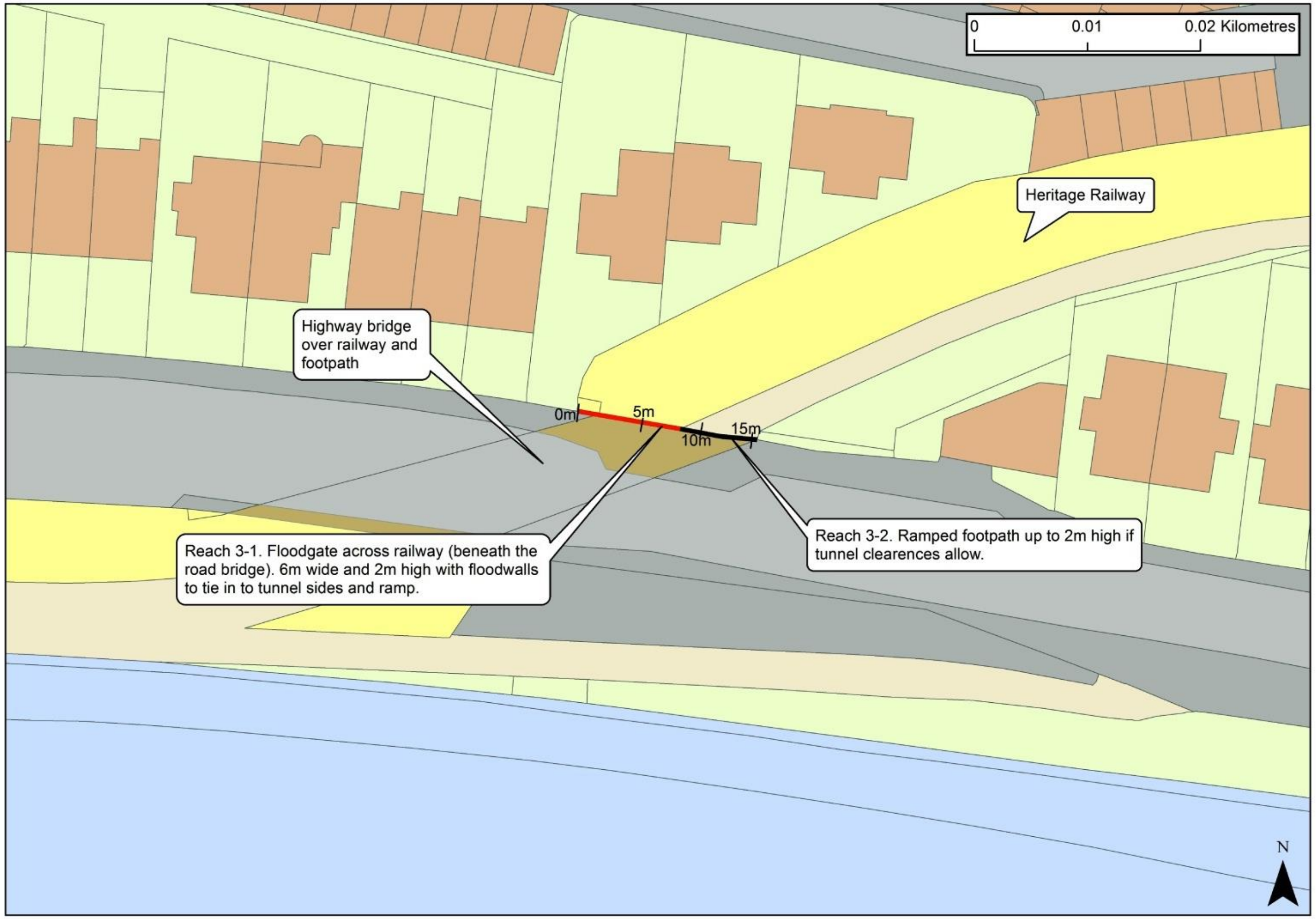

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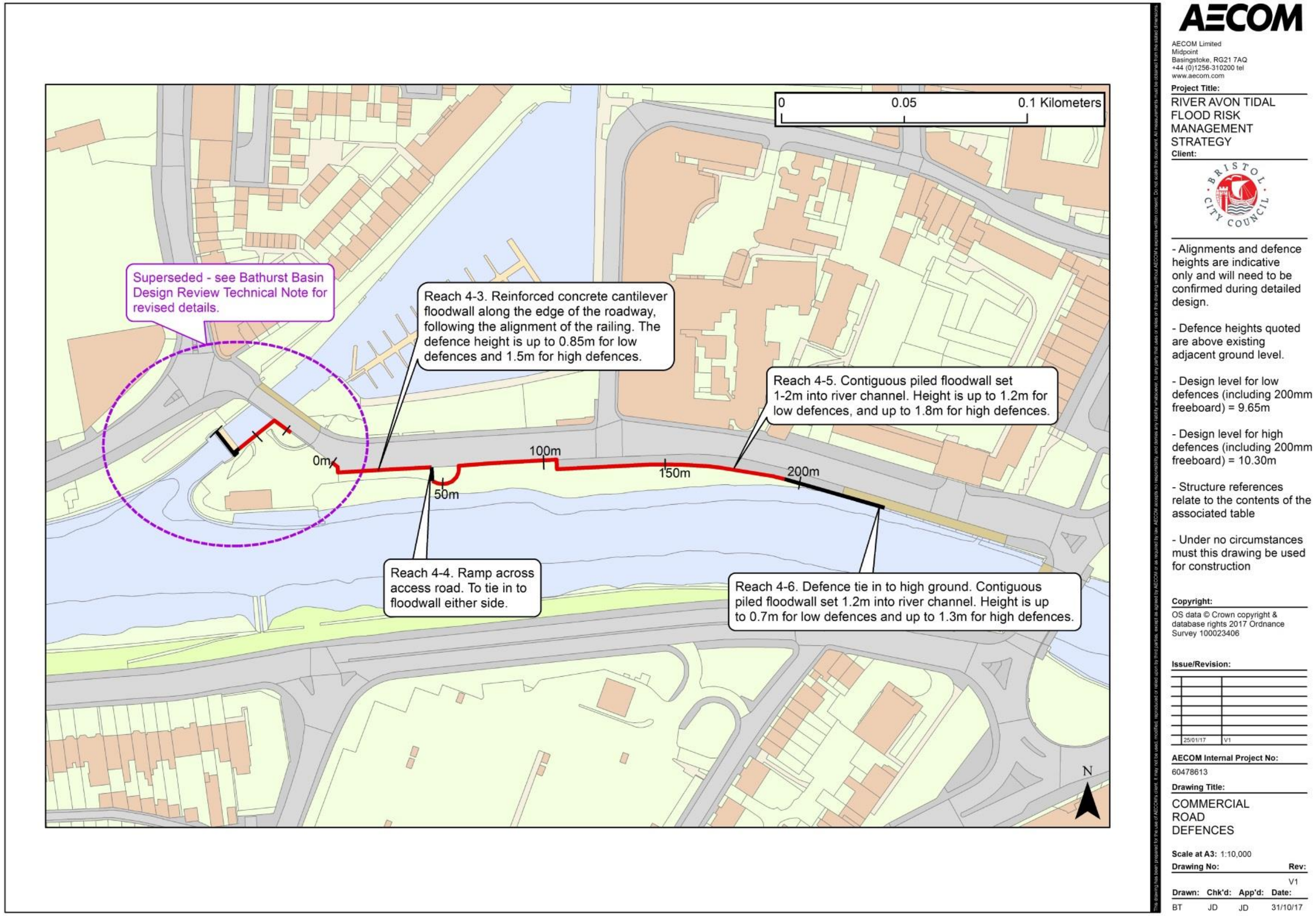

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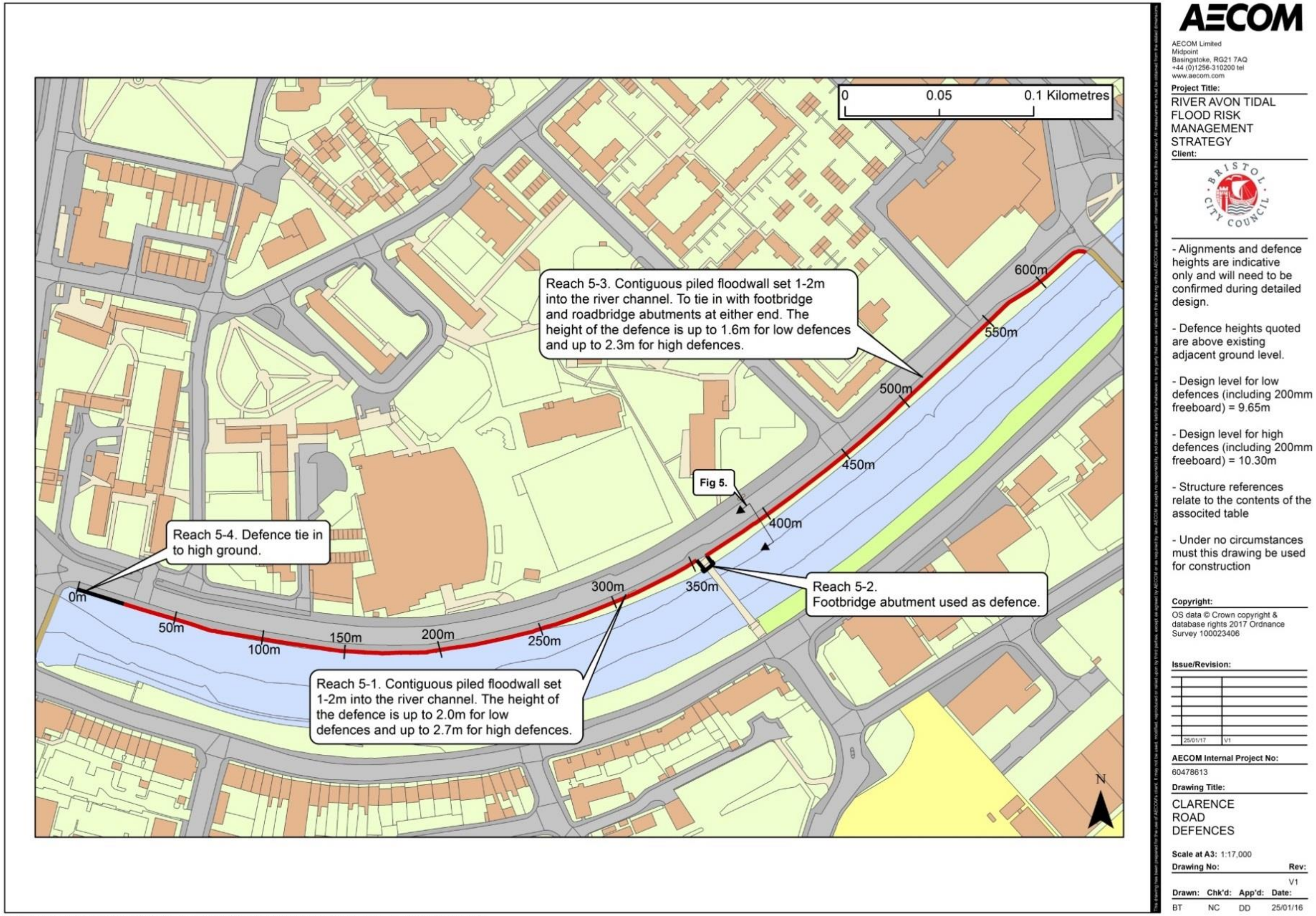

0
0.05
0.1 Kilometres
Reach 5-3. Contiguous piled floodwall set 1-2m into the river channel. To tie in with footbridge and roadbridge abutments at either end. The height of the defence is up to 1.6m for low defences and up to 2.3m for high defences.
Reach 5-4. Defence tie in to high ground.
Fig 5.
Reach 5-2.
Footbridge abutment used as defence.
Reach 5-1. Contiguous piled floodwall set 1-2m into the river channel. The height of the defence is up to 2.0m for low defences and up to 2.7m for high defences.
0m
50m
100m
150m
200m
250m
300m
350m
400m
450m
500m
550m
600m
N
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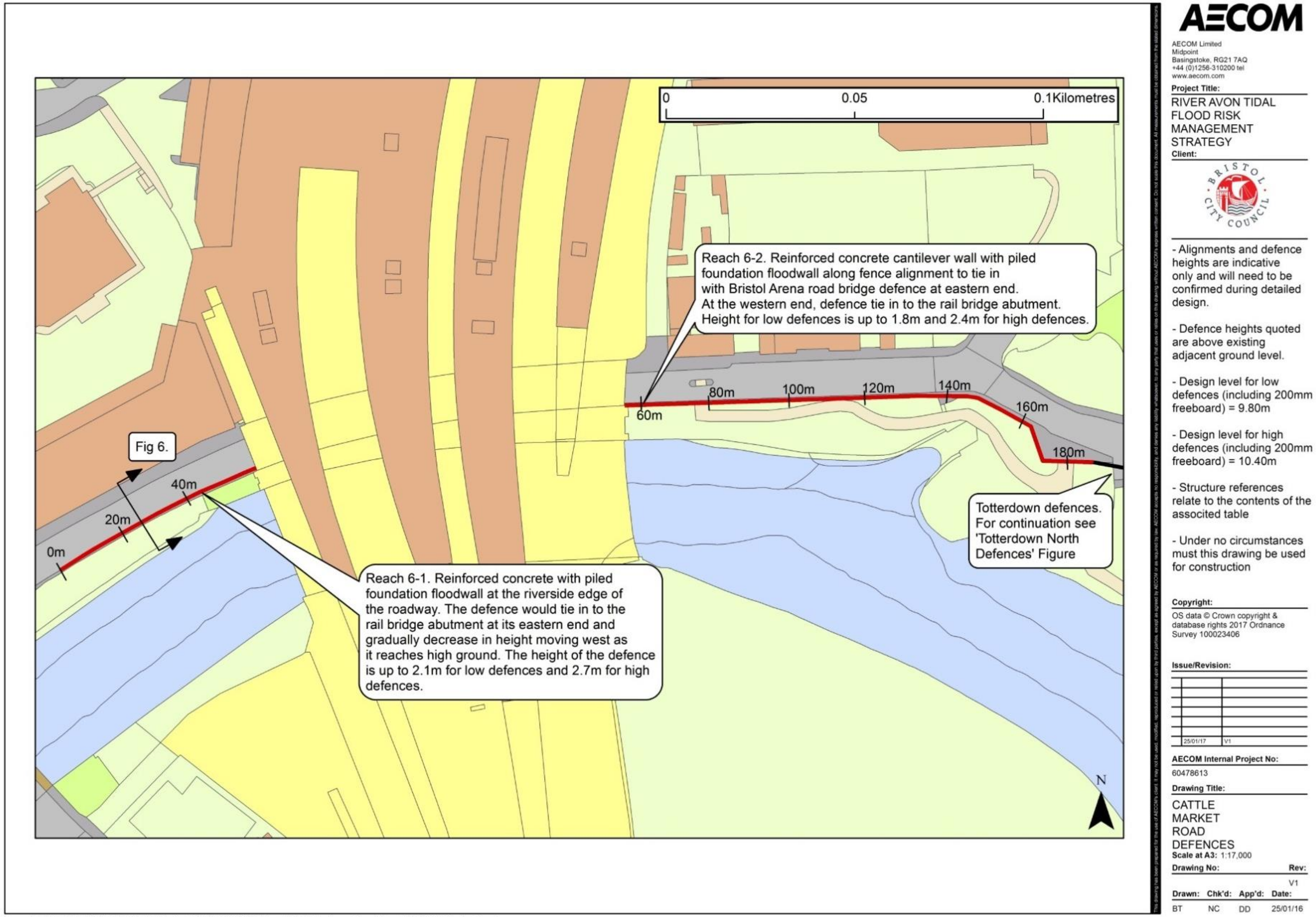

0
0.05
0.1Kilometres
Reach 6-2. Reinforced concrete cantilever wall with piled foundation floodwall along fence alignment to tie in with Bristol Arena road bridge defence at eastern end.
At the western end, defence tie in to the rail bridge abutment.
Height for low defences is up to 1.8m and 2.4m for high defences.
0m
20m
40m
60m
80m
100m
120m
140m
160m
180m
Fig 6.
Totterdown defences. For continuation see 'Totterdown North Defences' Figure
Reach 6-1. Reinforced concrete with piled foundation floodwall at the riverside edge of the roadway. The defence would tie in to the rail bridge abutment at its eastern end and gradually decrease in height moving west as it reaches high ground. The height of the defence is up to 2.1m for low defences and 2.7m for high defences.
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Client:
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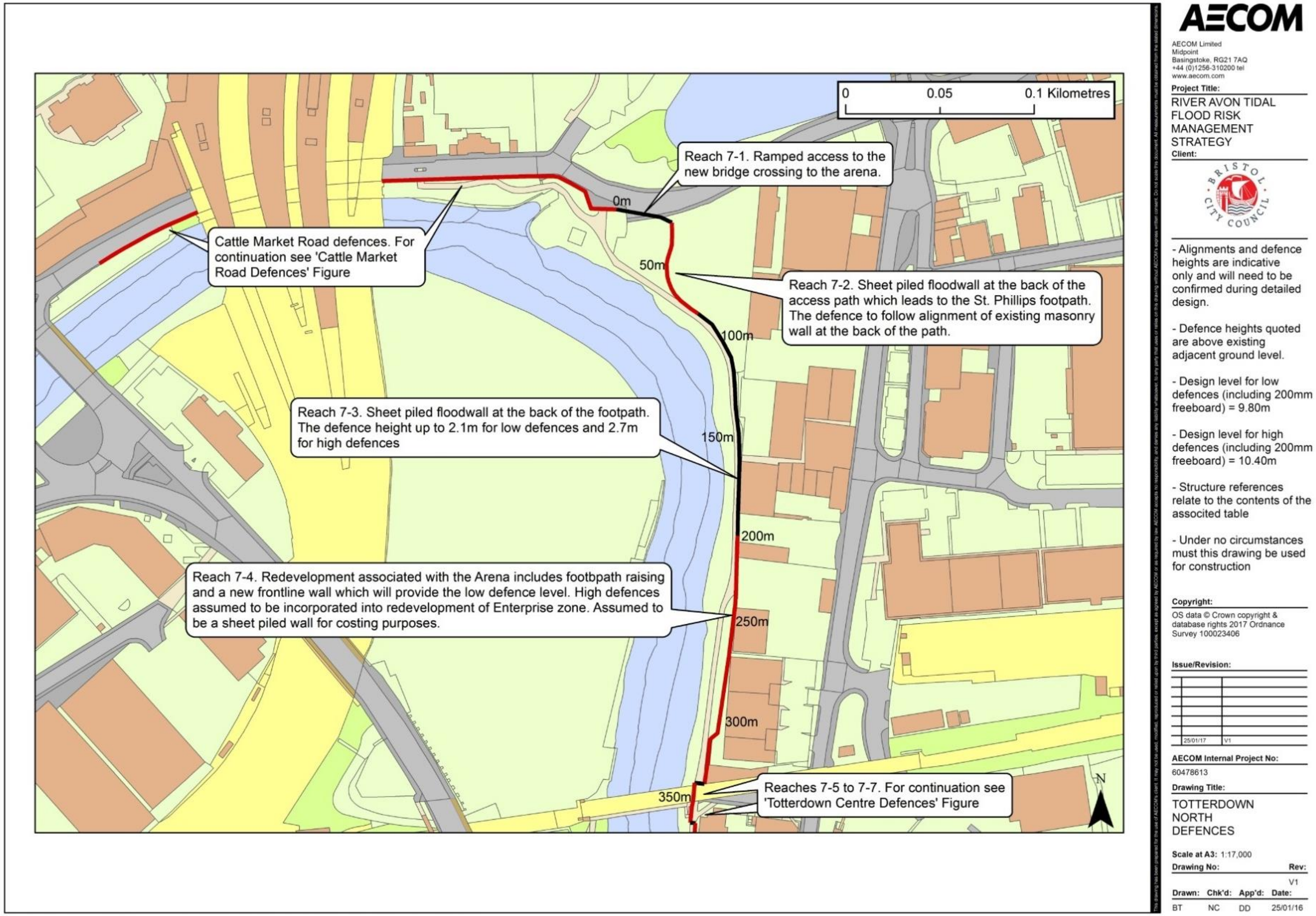

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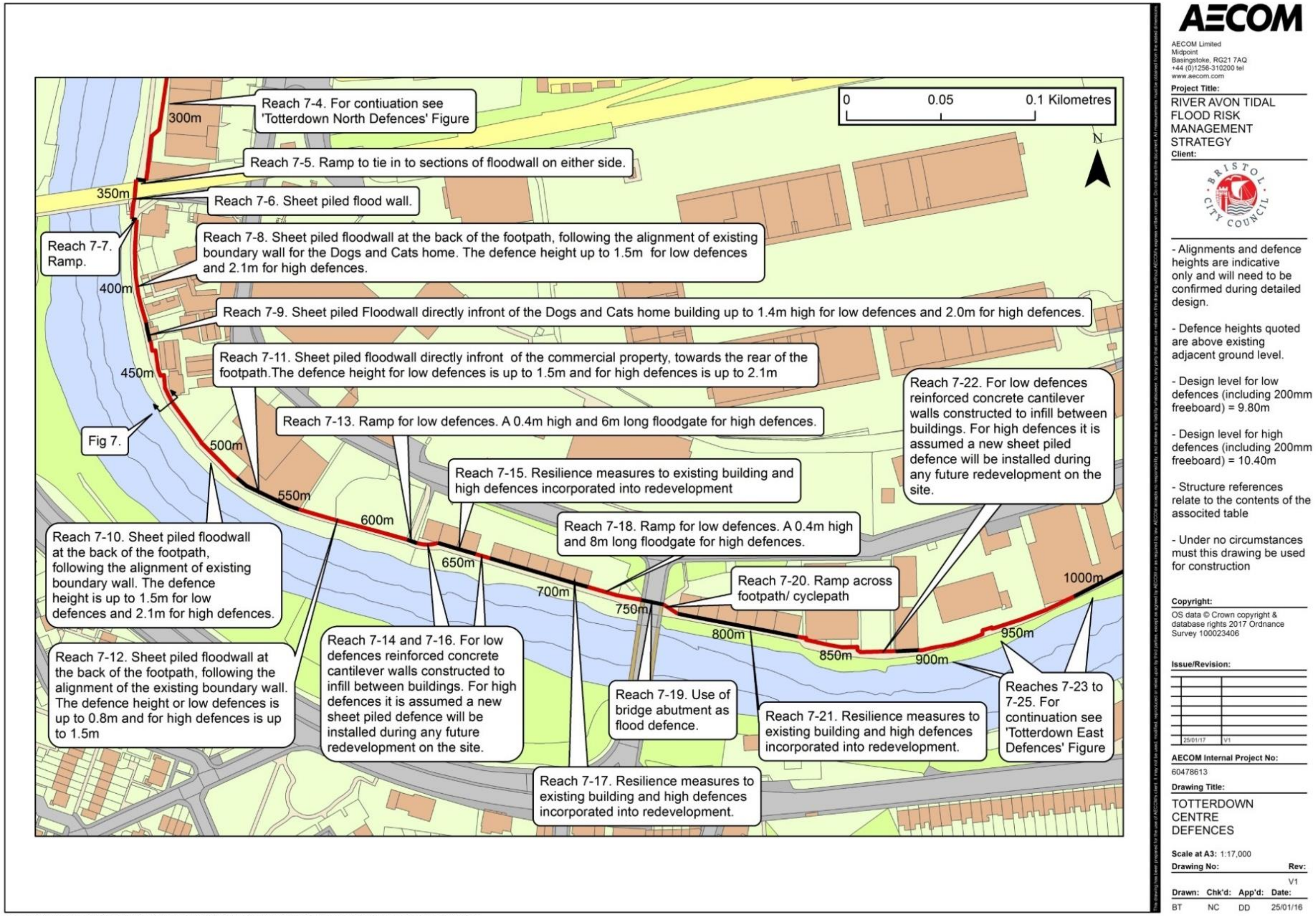
Reach 7-4. For contiuation see 'Totterdown North Defences' Figure
Reach 7-5. Ramp to tie in to sections of floodwall on either side.
Reach 7-6. Sheet piled flood wall.
Reach 7-7. Ramp.
Reach 7-8. Sheet piled floodwall at the back of the footpath, following the alignment of existing boundary wall for the Dogs and Cats home. The defence height up to 1.5m for low defences and 2.1m for high defences.
Reach 7-9. Sheet piled Floodwall directly infront of the Dogs and Cats home building up to 1.4m high for low defences and 2.0m for high defences.
Reach 7-11. Sheet piled floodwall directly infront of the commercial property, towards the rear of the footpath.The defence height for low defences is up to 1.5m and for high defences is up to 2.1m
Fig 7.
Reach 7-13. Ramp for low defences. A 0.4m high and 6m long floodgate for high defences.
Reach 7-15. Resilience measures to existing building and high defences incorporated into redevelopment
Reach 7-22. For low defences reinforced concrete cantilever walls constructed to infill between buildings. For high defences it is assumed a new sheet piled defence will be installed during any future redevelopment on the site.
Reach 7-18. Ramp for low defences. A 0.4m high and 8m long floodgate for high defences.
Reach 7-10. Sheet piled floodwall at the back of the footpath, following the alignment of existing boundary wall. The defence height is up to 1.5m for low defences and 2.1m for high defences.
Reach 7-20. Ramp across footpath/ cyclepath
Reach 7-12. Sheet piled floodwall at the back of the footpath, following the alignment of the existing boundary wall. The defence height or low defences is up to 0.8m and for high defences is up to 1.5m
Reach 7-14 and 7-16. For low defences reinforced concrete cantilever walls constructed to infill between buildings. For high defences it is assumed a new sheet piled defence will be installed during any future redevelopment on the site.
Reach 7-19. Use of bridge abutment as flood defence.
Reach 7-21. Resilience measures to existing building and high defences incorporated into redevelopment.
Reaches 7-23 to 7-25. For continuation see 'Totterdown East Defences' Figure
Reach 7-17. Resilience measures to existing building and high defences incorporated into redevelopment.
300m
350m
400m
450m
500m
550m
600m
650m
700m
750m
800m
850m
900m
950m
1000m
0
0.05
0.1 Kilometres
N
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RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY
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Drawing No:
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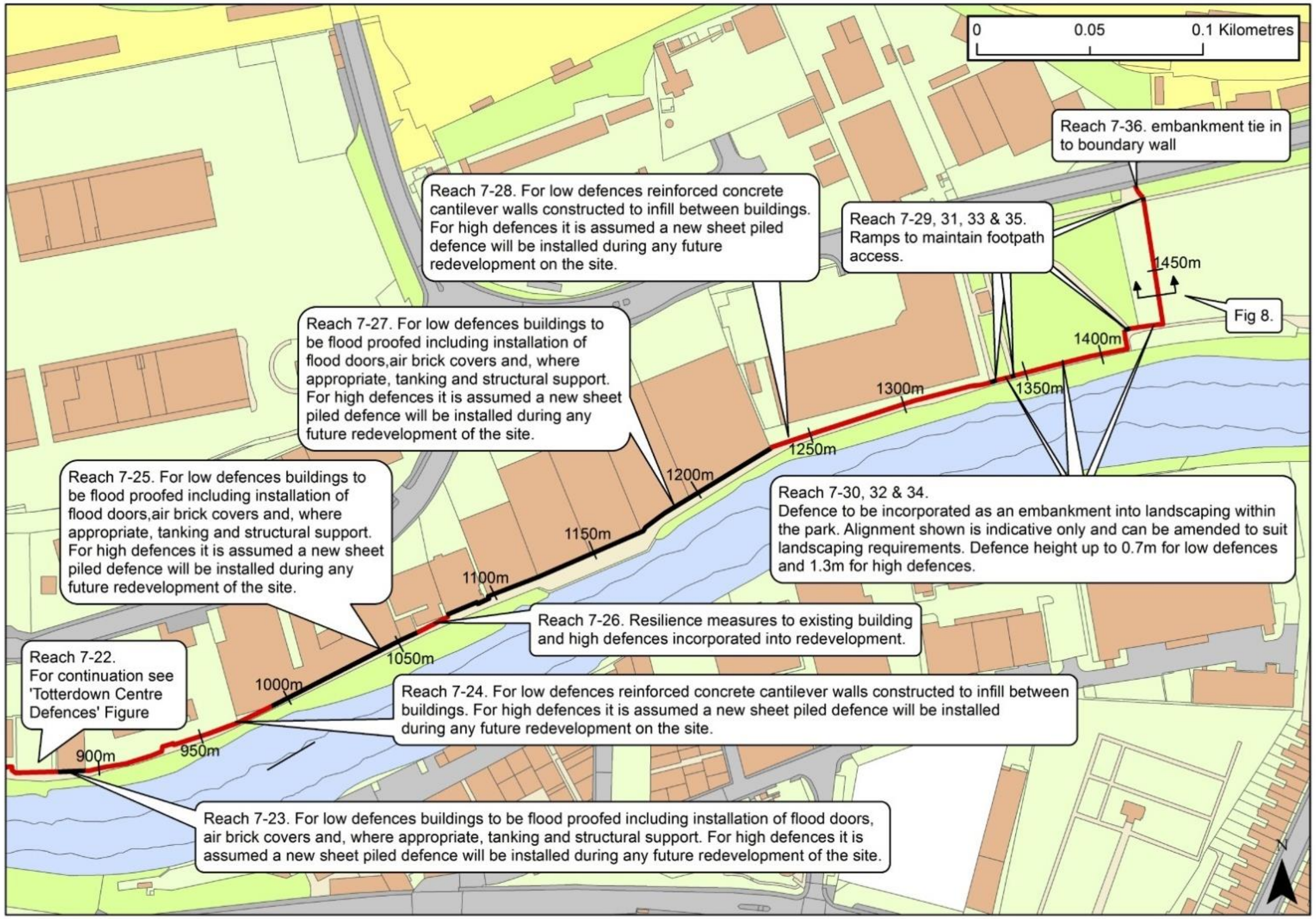

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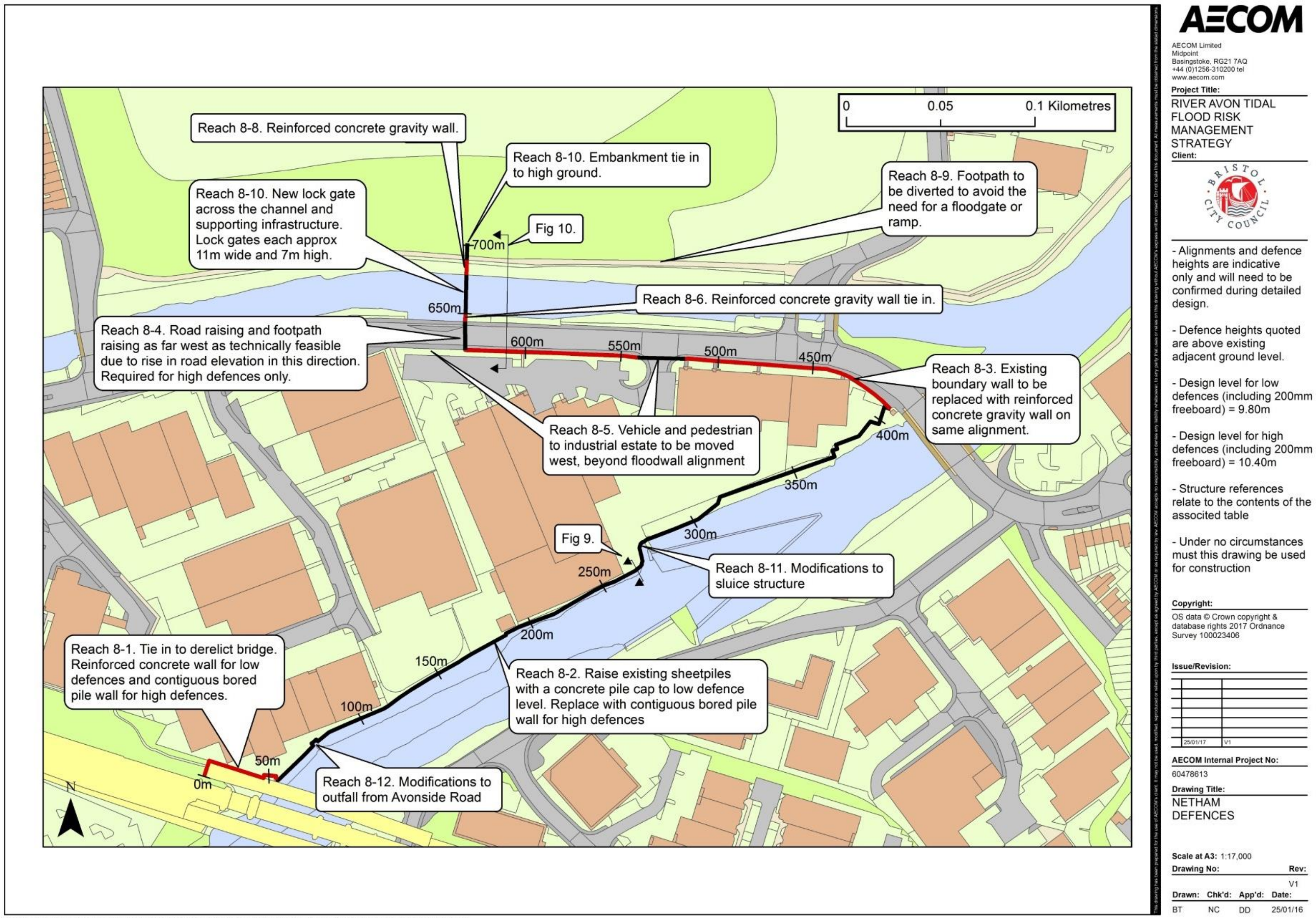
0
0.05
0.1 Kilometres
Reach 8-8. Reinforced concrete gravity wall.
Reach 8-10. Embankment tie in to high ground.
Reach 8-10. New lock gate across the channel and supporting infrastructure. Lock gates each approx 11m wide and 7m high.
Fig 10.
Reach 8-9. Footpath to be diverted to avoid the need for a floodgate or ramp.
Reach 8-6. Reinforced concrete gravity wall tie in.
Reach 8-4. Road raising and footpath raising as far west as technically feasible due to rise in road elevation in this direction. Required for high defences only.
Reach 8-3. Existing boundary wall to be replaced with reinforced concrete gravity wall on same alignment.
Reach 8-5. Vehicle and pedestrian to industrial estate to be moved west, beyond floodwall alignment
Fig 9.
Reach 8-11. Modifications to sluice structure
Reach 8-1. Tie in to derelict bridge. Reinforced concrete wall for low defences and contiguous bored pile wall for high defences.
Reach 8-2. Raise existing sheetpiles with a concrete pile cap to low defence level. Replace with contiguous bored pile wall for high defences
Reach 8-12. Modifications to outfall from Avonside Road
0m
50m
100m
150m
200m
250m
300m
350m
400m
450m
500m
550m
600m
650m
700m
N
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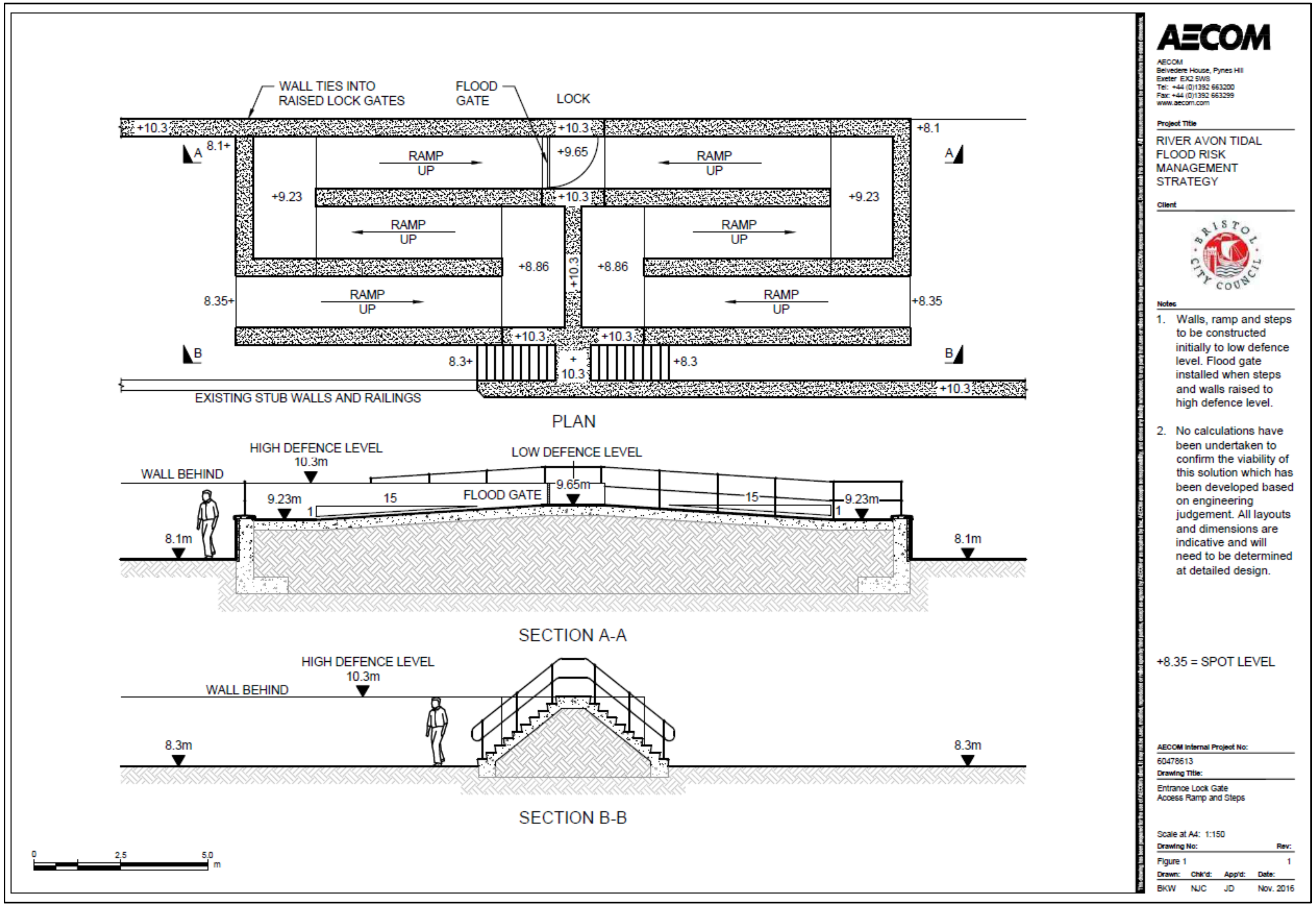
Appendix D – Defence cross sections


WALL TIES INTO
RAISED LOCK GATES
FLOOD
GATE
LOCK
+10.3
+8.1
8.1+
+9.65
RAMP
UP
+9.23
+8.86
+10.3
8.35+
+8.35
8.3+
+8.3
EXISTING STUB WALLS AND RAILINGS
PLAN
HIGH DEFENCE LEVEL
10.3m
LOW DEFENCE LEVEL
WALL BEHIND
9.23m
15
FLOOD GATE
9.65m
8.1m
SECTION A-A
8.3m
SECTION B-B
0
2.5
5.0
m
AECOM
AECOM
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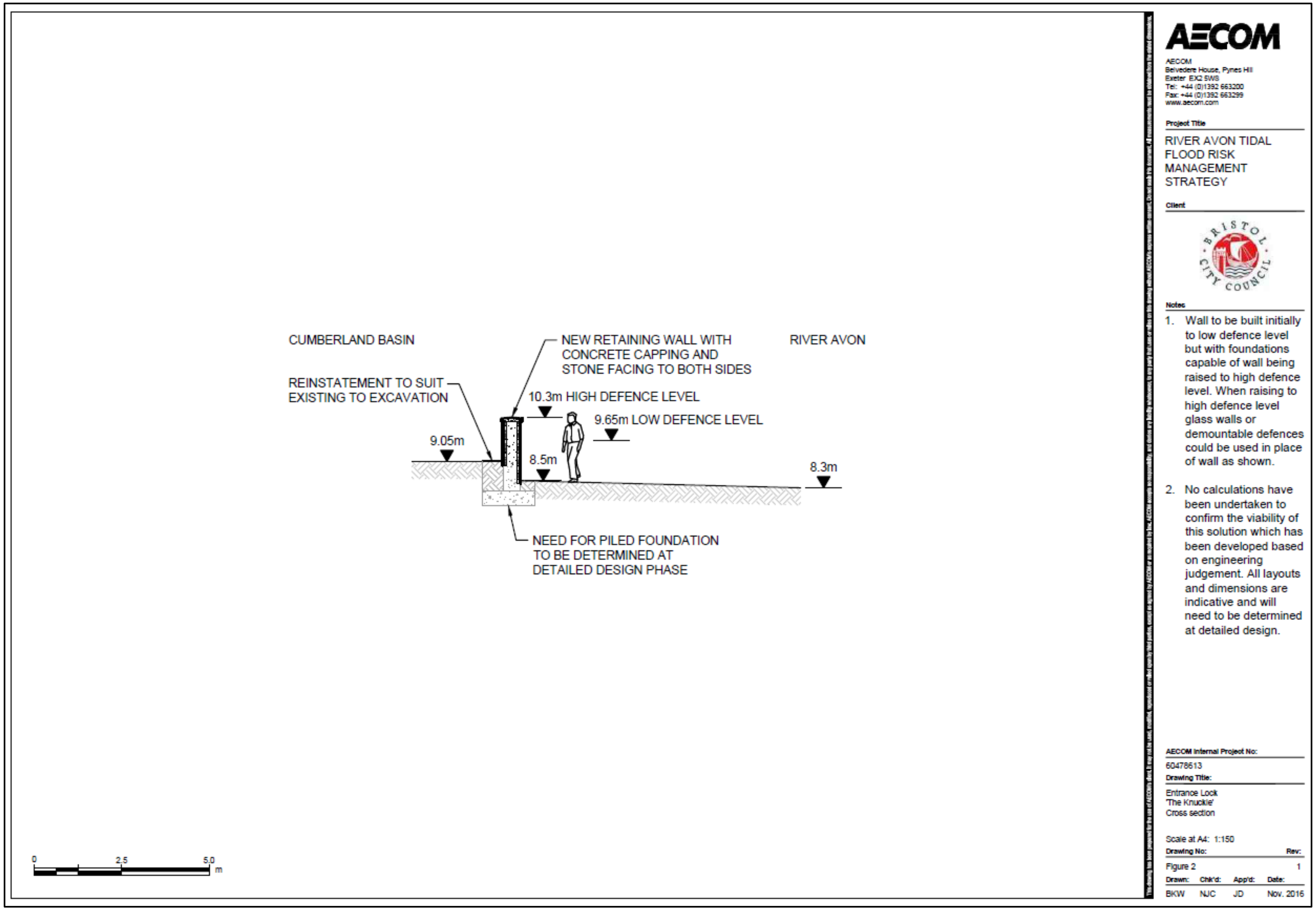
Project Title
RIVER AVON TIDAL
FLOOD RISK
MANAGEMENT
STRATEGY
Client
BRISTOL CITY COUNCIL
Notes
1. Walls, ramp and steps to be constructed initially to low defence level. Flood gate installed when steps and walls raised to high defence level.
2. No calculations have been undertaken to confirm the viability of this solution which has been developed based on engineering judgement. All layouts and dimensions are indicative and will need to be determined at detailed design.
+8.35 = SPOT LEVEL
AECOM Internal Project No:
60478613
Drawing Title:
Entrance Lock Gate
Access Ramp and Steps
Scale at A4: 1:150
Drawing No:
Rev:
Figure 1
1
Drawn:
Chk'd:
App'd:
Date:
BKW
NJC
JD
Nov. 2016



CUMBERLAND BASIN
NEW RETAINING WALL WITH CONCRETE CAPPING AND STONE FACING TO BOTH SIDES
RIVER AVON
REINSTATEMENT TO SUIT EXISTING TO EXCAVATION
10.3m HIGH DEFENCE LEVEL
9.65m LOW DEFENCE LEVEL
9.05m
8.5m
8.3m
NEED FOR PILED FOUNDATION TO BE DETERMINED AT DETAILED DESIGN PHASE
0
2.5
5.0
m
AECOM
Belvedere House, Pynes Hill
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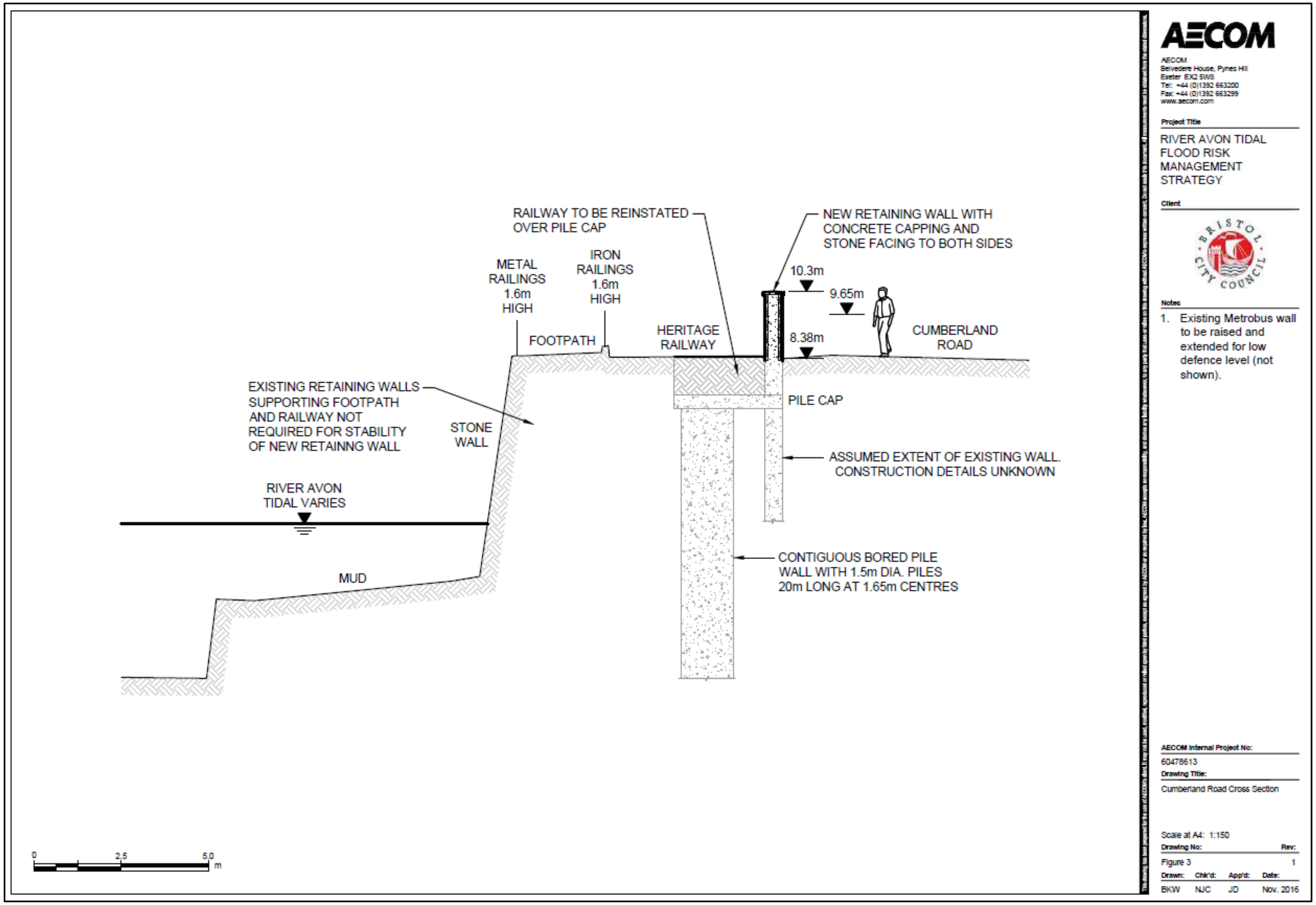
Fax: +44 (0)1392 663299
www.aecom.com
Project Title
RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY
Client
BRISTOL CITY COUNCIL
Notes
1. Wall to be built initially to low defence level but with foundations capable of wall being raised to high defence level. When raising to high defence level glass walls or demountable defences could be used in place of wall as shown.
2. No calculations have been undertaken to confirm the viability of this solution which has been developed based on engineering judgement. All layouts and dimensions are indicative and will need to be determined at detailed design.
AECOM Internal Project No:
60478613
Drawing Title:
Entrance Lock
'The Knuckle'
Cross section
Scale at A4: 1:150
Drawing No:
Rev:
Figure 2
1
Drawn:
Chk'd:
App'd:
Date:
BKW
NJC
JD
Nov. 2016


RAILWAY TO BE REINSTATED
OVER PILE CAP
NEW RETAINING WALL WITH
CONCRETE CAPPING AND
STONE FACING TO BOTH SIDES
METAL
RAILINGS
1.6m
HIGH
IRON
RAILINGS
1.6m
HIGH
10.3m
9.65m
8.38m
FOOTPATH
HERITAGE
RAILWAY
CUMBERLAND
ROAD
EXISTING RETAINING WALLS
SUPPORTING FOOTPATH
AND RAILWAY NOT
REQUIRED FOR STABILITY
OF NEW RETAINNG WALL
STONE
WALL
PILE CAP
ASSUMED EXTENT OF EXISTING WALL.
CONSTRUCTION DETAILS UNKNOWN
RIVER AVON
TIDAL VARIES
MUD
CONTIGUOUS BORED PILE
WALL WITH 1.5m DIA. PILES
20m LONG AT 1.65m CENTRES
0
2.5
5.0
m
AECOM
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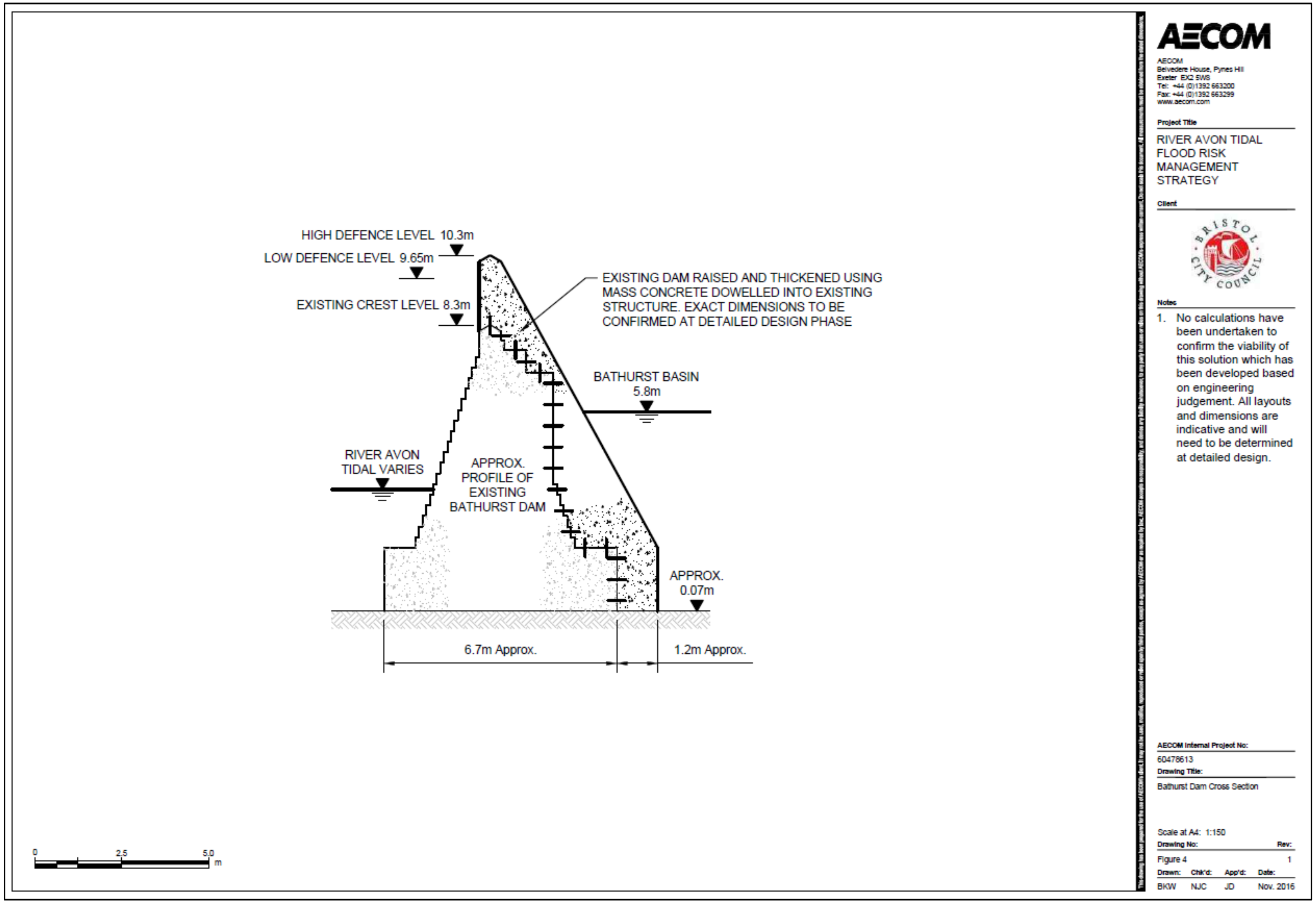
www.aecom.com
Project Title
RIVER AVON TIDAL
FLOOD RISK
MANAGEMENT
STRATEGY
Client
BRISTOL CITY COUNCIL
Notes
1. Existing Metrobus wall to be raised and extended for low defence level (not shown).
AECOM Internal Project No:
60478613
Drawing Title:
Cumberland Road Cross Section
Scale at A4: 1:150
Drawing No:
Rev:
Figure 3
1
Drawn:
Chk'd:
App'd:
Date:
BKW
NJC
JD
Nov. 2016


HIGH DEFENCE LEVEL 10.3m
LOW DEFENCE LEVEL 9.65m
EXISTING CREST LEVEL 8.3m
EXISTING DAM RAISED AND THICKENED USING MASS CONCRETE DOWELLED INTO EXISTING STRUCTURE. EXACT DIMENSIONS TO BE CONFIRMED AT DETAILED DESIGN PHASE
BATHURST BASIN 5.8m
RIVER AVON TIDAL VARIES
APPROX. PROFILE OF EXISTING BATHURST DAM
APPROX. 0.07m
6.7m Approx.
1.2m Approx.
0
2.5
5.0
m
AECOM
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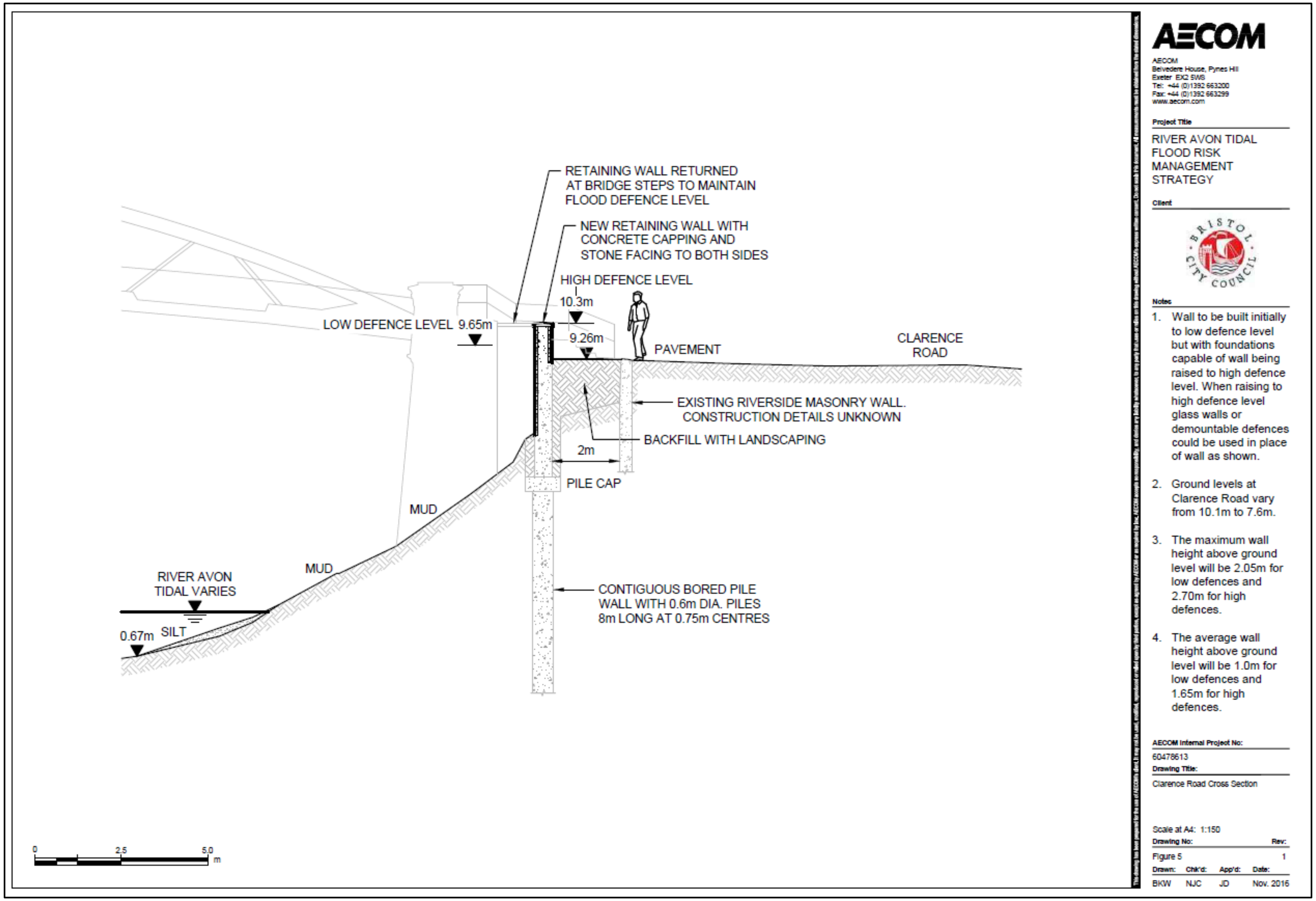
Project Title
RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY
Client
BRISTOL CITY COUNCIL
Notes
1. No calculations have been undertaken to confirm the viability of this solution which has been developed based on engineering judgement. All layouts and dimensions are indicative and will need to be determined at detailed design.
AECOM Internal Project No:
60478613
Drawing Title:
Bathurst Dam Cross Section
Scale at A4: 1:150
Drawing No: Figure 4
Rev: 1
Drawn: BKW
Chk'd: NJC
App'd: JD
Date: Nov. 2016


RETAINING WALL RETURNED
AT BRIDGE STEPS TO MAINTAIN
FLOOD DEFENCE LEVEL
NEW RETAINING WALL WITH
CONCRETE CAPPING AND
STONE FACING TO BOTH SIDES
HIGH DEFENCE LEVEL
10.3m
LOW DEFENCE LEVEL 9.65m
9.26m
PAVEMENT
CLARENCE
ROAD
EXISTING RIVERSIDE MASONRY WALL.
CONSTRUCTION DETAILS UNKNOWN
BACKFILL WITH LANDSCAPING
2m
PILE CAP
MUD
MUD
RIVER AVON
TIDAL VARIES
0.67m
SILT
CONTIGUOUS BORED PILE
WALL WITH 0.6m DIA. PILES
8m LONG AT 0.75m CENTRES
0
2.5
5.0
m
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Fax: +44 (0)1392 663299
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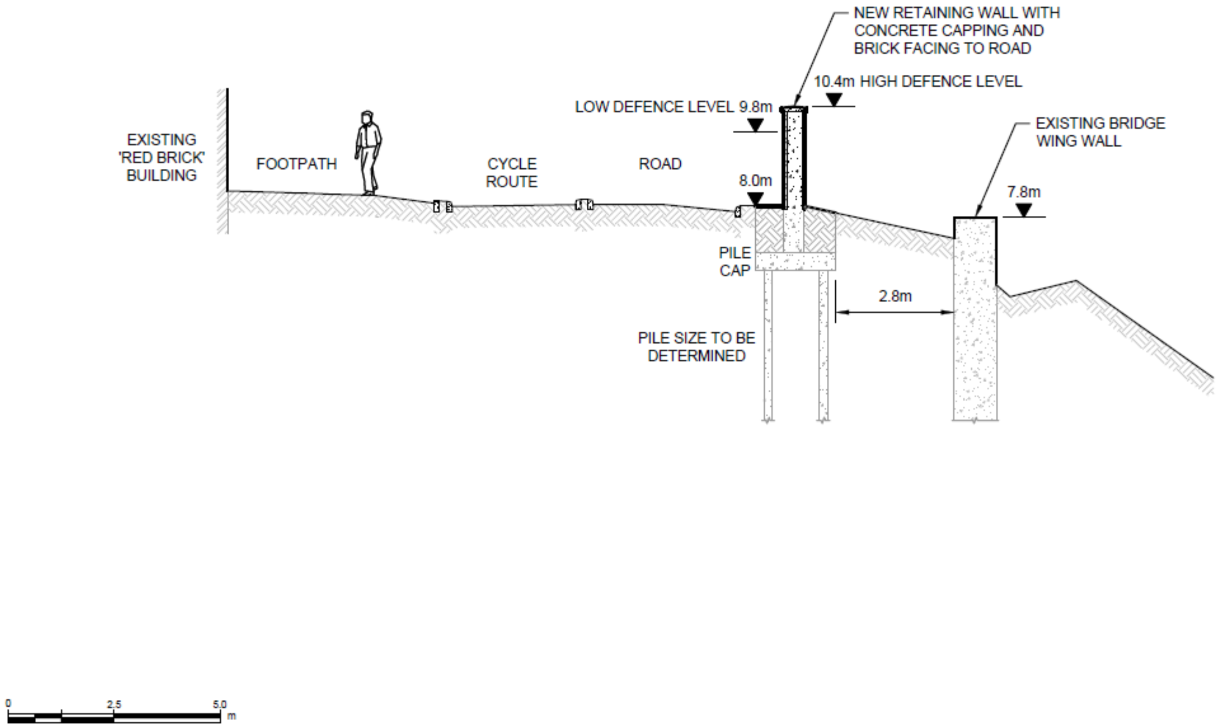
Project Title
RIVER AVON TIDAL
FLOOD RISK
MANAGEMENT
STRATEGY
Client
Notes
1. Wall to be built initially to low defence level but with foundations capable of wall being raised to high defence level. When raising to high defence level glass walls or demountable defences could be used in place of wall as shown.
2. Ground levels at Clarence Road vary from 10.1m to 7.6m.
3. The maximum wall height above ground level will be 2.05m for low defences and 2.70m for high defences.
4. The average wall height above ground level will be 1.0m for low defences and 1.65m for high defences.
AECOM Internal Project No:
60478613
Drawing Title:
Clarence Road Cross Section
Scale at A4: 1:150
Drawing No:
Rev:
Figure 5
1
Drawn: Chk'd: App'd: Date:
BKW NJC JD Nov. 2016



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Project Title

RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY

Client

BRISTOL CITY COUNCIL

Notes

1. Wall to be built initially to low defence level but with foundations capable of wall being raised to high defence level. When raising to high defence level glass walls or demountable defences could be used in place of wall as shown.

2. No calculations have been undertaken to confirm the viability of this solution which has been developed based on engineering judgement. All layouts and dimensions are indicative and will need to be determined at detailed design.

AECOM Internal Project No:

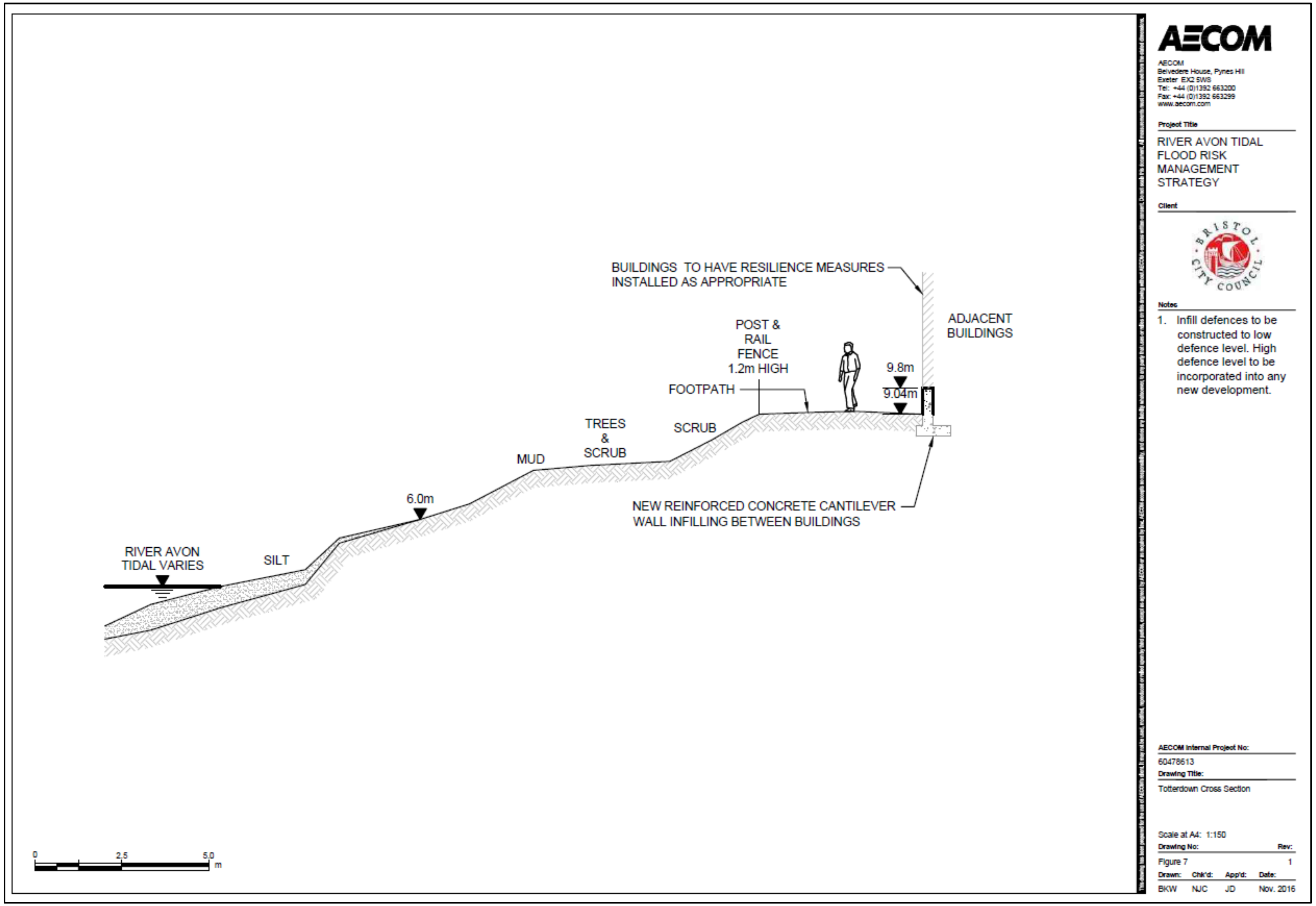
60478613

Drawing Title:

Cattle Market Road (West Side) Cross Section

Scale at A4: 1:150

Drawing No:			Rev:
Figure 6			1
Drawn:	**Chk'd:**	**App'd:**	**Date:**
BKW	NJC	JD	Nov. 2016



BUILDINGS TO HAVE RESILIENCE MEASURES
INSTALLED AS APPROPRIATE
ADJACENT
BUILDINGS
POST &
RAIL
FENCE
1.2m HIGH
9.8m
9.04m
FOOTPATH
TREES
&
SCRUB
SCRUB
MUD
6.0m
NEW REINFORCED CONCRETE CANTILEVER
WALL INFILLING BETWEEN BUILDINGS
RIVER AVON
TIDAL VARIES
SILT
0
2.5
5.0
m
AECOM
AECOM
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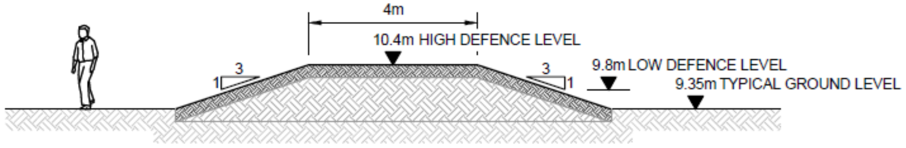
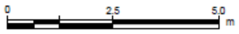
Project Title
RIVER AVON TIDAL
FLOOD RISK
MANAGEMENT
STRATEGY
Client
BRISTOL CITY COUNCIL
Notes
1. Infill defences to be constructed to low defence level. High defence level to be incorporated into any new development.
AECOM Internal Project No:
60478613
Drawing Title:
Totterdown Cross Section
Scale at A4: 1:150
Drawing No:
Rev:
Figure 7
1
Drawn: Chk'd: App'd: Date:
BKW NJC JD Nov. 2016





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Project Title

RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY

Client

BRISTOL CITY COUNCIL

Notes

1. Slopes to be 1 (vertical) in 3 (horizontal) or slacker to suit landscaping within park.
2. Crest width 4m minimum.
3. Embankment to have clay core with topsoil and appropriate seeding on top.
4. Ground levels in the park vary from 10.2m to 9.1m.
5. The maximum height of the embankment will be 0.7m for low defences and 1.3m for high defences.
7. The average height of the embankment will be 0.6m for low defences and 1.2m for high defences.

AECOM Internal Project No: 60478613

Drawing Title: Sparke Evans Park St. Philips Embankment Cross Section

Scale at A4: 1:150

Drawing No:	Rev:
Figure 8	1

Drawn:	Chk'd:	App'd:	Date:
BKW	NJC	JD	Nov. 2016

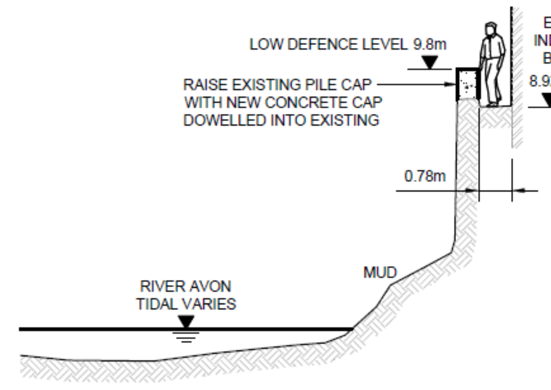

Fig. 9a - Low Defence Level

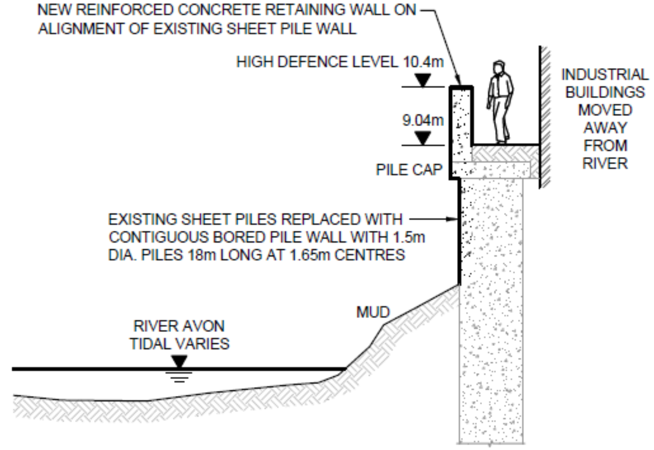

Fig. 9b - High Defence Level

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Project Title

RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY

Client

BRISTOL CITY COUNCIL

Notes

1. Calculations have been undertaken to confirm the viability of the high defence level solution 9b only. However, in both solutions layouts and dimensions are indicative and will need to be determined at detailed design.
2. It is assumed that the high defences shall be incorporated into any future redevelopment of the adjacent site to avoid conflicts with existing structures.

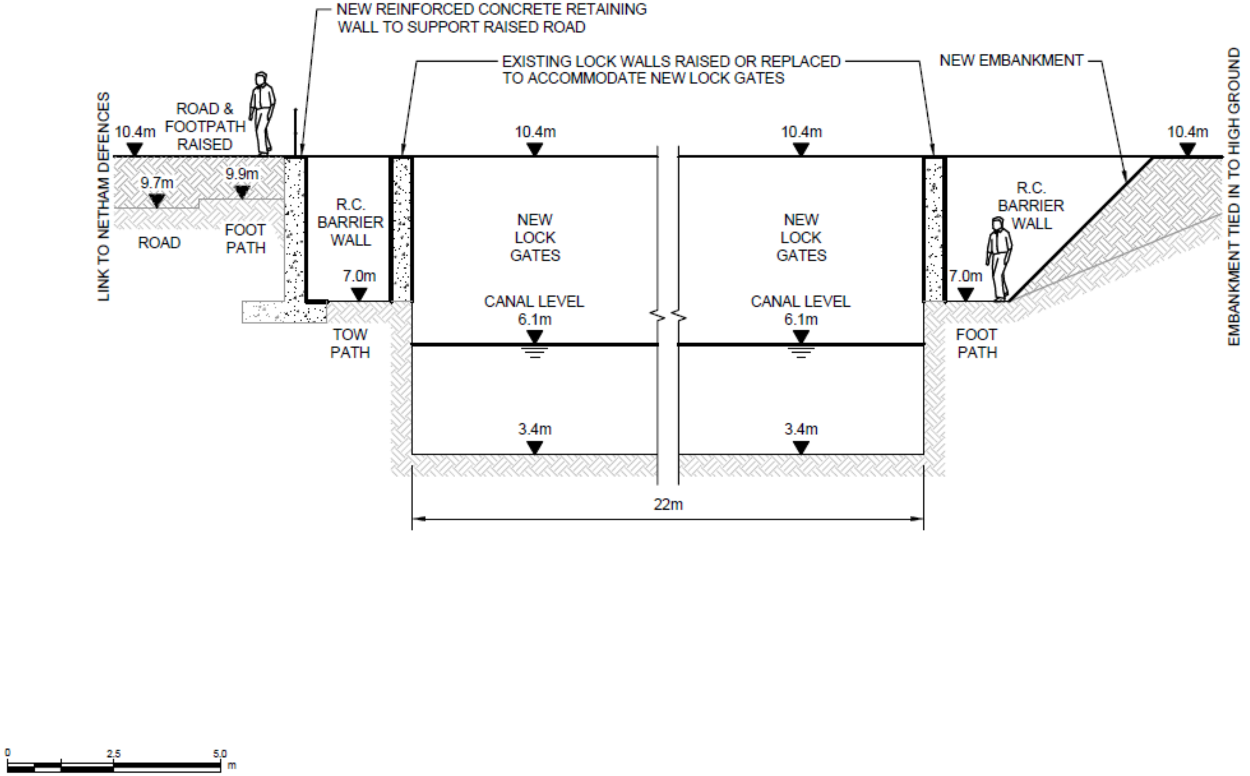
AECOM Internal Project No: 60478613

Drawing Title: Netham Cross Section

Scale at A4: 1:150

Drawing No:	Rev:
Figure 9	1

Drawn:	Chk'd:	App'd:	Date:
BKW	NJC	JD	Nov. 2016



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Project Title

RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY

Client

Notes

1. All levels and dimensions are estimated as available topographical survey does not extend to this point.
2. Foundation details not shown.
3. It is assumed that access along lock side tow path and footpath can be severed or diverted so no flood gates or ramps are required.

AECOM Internal Project No: 60478613

Drawing Title: Netham Lock Cross Section

Scale at A4: 1:150

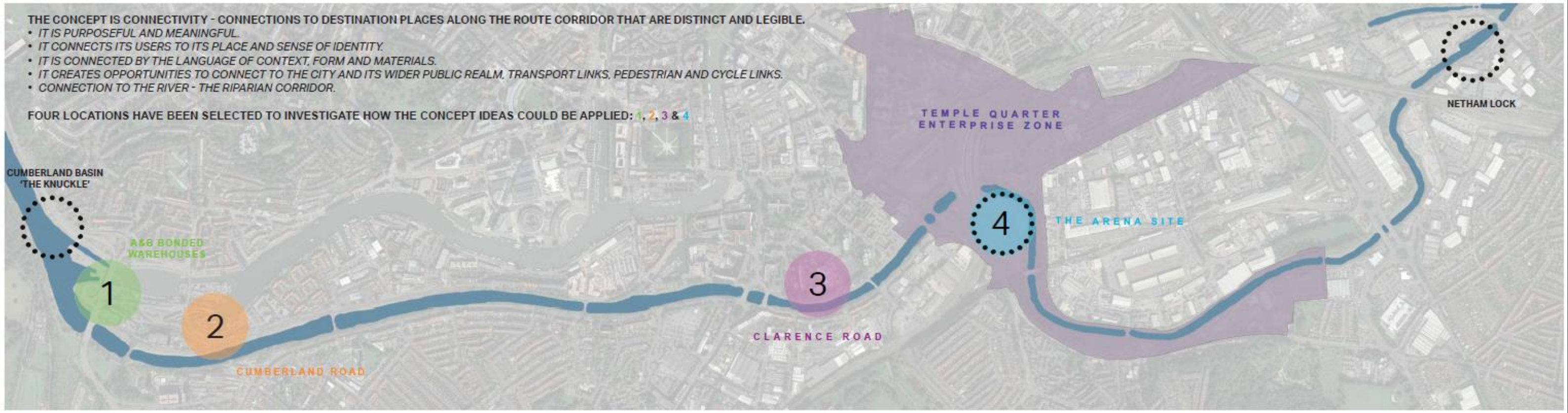
Drawing No:	Rev:
Figure 10	1

Drawn:	Chk'd:	App'd:	Date:
BKW	NJC	JD	Nov. 2016

Appendix E – Defence Visualisations


Littlehampton, West Sussex
Southey Hill, Cumbria
Carlisle
Upton, Worcestershire
Keswick, Cumbria
Keswick, Cumbria
Wisbech, Cambridgeshire
Latchford, Cheshire
Dresden, River Elbe
AECOM
Project: River Avon Tidal Flood Risk Management Strategy
Sheet: Flood Defence Examples Board

Appendix F – New Cut Greenway



THE NEW CUT GREENWAY REPRESENTS A LINEAR RESILIENT CORRIDOR THAT WILL PROTECT, PRESERVE AND ENHANCE ITS SURROUNDINGS.

LINEARITY AND FLOW - REPRESENTING A SERIES OF INTERVENTIONS ALONG THE ROUTE.

THE DEFENCE PROJECT IS TO PROTECT THE CITY FROM FUTURE POTENTIAL FLOOD LEVELS BUT CAN ALSO OFFER OPPORTUNITY FOR RELIEF FROM VEHICULAR TRAFFIC, ROAD NOISE AND POLLUTION.

KEY PRINCIPLES OF THE SCHEME ARE:
- *PROTECTION*
- *RELIEF*
- *ADAPTABILITY*
- *VERSATILITY*
- *REST POINTS*
- *VIEW POINTS*
- *USEFULNESS*
- *PLAYFULNESS*
- *EXCITEMENT*

DESIGN STATEMENT

The project has the opportunity to regenerate and enhance the riverside environment and provide a high quality, legible link along the river corridor. It can provide amenity and ecological benefits and strongly contribute towards a green infrastructure strategy for the 'greenway'. It has potential for a riverside trail linking Cumberland basin, the Arena site and further to Netham Park encompassing amenity, education, ecology and commuting.

The concept pages explore opportunities to create a suite of materials, form, design, furniture and strategies that are adaptable to varying context and requirements along the river route, to create a legible identity and recognition of the greenway corridor. although various locations have been selected, the ideas and concepts are not confined to any one location and can be adapted to the various interventions.

AECOM | Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **The Concept**

BONDED WAREHOUSES

The route adjacent to the 'Bonded Warehouses'.

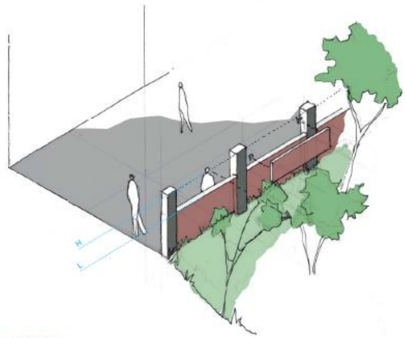
Industrial heritage and materials (red & black brick, Corten steel and timber).

Consider vehicular exclusion to create a comfortable and safe walking and cycling route.

Allow views to river by considering raising existing ground levels and/or elevated platforms.

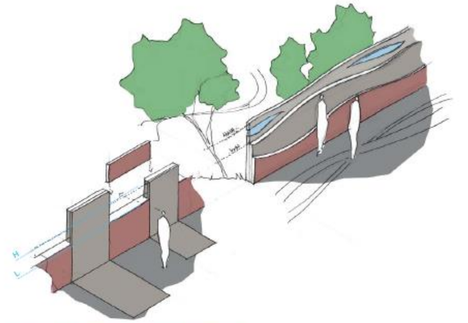
Allow natural regeneration plant growth of bank edges.

Sheet pile floodwall following the edge of roadway. Defence height is up to 1.15m for low defences and 1.8m for high defences.



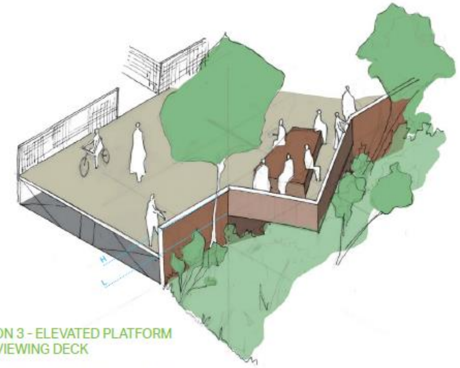
OPTION 1 - PILLAR WALL

Retaining existing ground level the flood defence wall is set at 1.15m high for low defence. The wall could be faced with red and black brick to directly connect with the bonded warehouses and/or individualistic material such as corton steel. The pillars indicate high defence levels of 1.8m where insert panels such as brick, glass or steel can be placed (or constructed) to allow full defence. These pillars could incorporate lighting to guide the route.



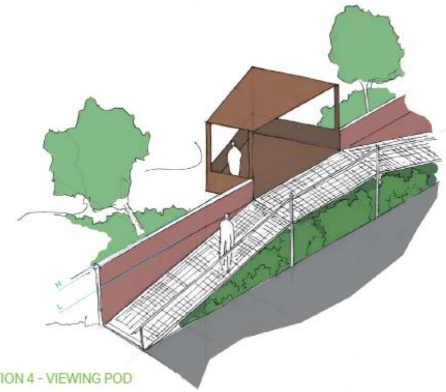
OPTION 2 - GREENING THE CORRIDOR

The wall can incorporate form / design and a variety of materials. The panels could be temporary demountable or more permanent and include viewing windows.



OPTION 3 - ELEVATED PLATFORM AND VIEWING DECK

An elevated deck allows permanent views over the full height defence wall and allows access to the warehouses and car parks. A cantilevered deck extrudes from the bank to create a seating & viewing platform.



OPTION 4 - VIEWING POD

Ramped look out / viewing pod. A ramp made of stainless steel grid panels leads to a sheltered viewing pod. A planting bed lies under the ramp to green the route. The viewing deck and pods could be used elsewhere along the river to highlight key views or points of interest and nature watching.

AECOM

Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **1. A & B Bonded Warehouses Concept Sketch Options**

C U M B E R L A N D   R O A D

Restricted public realm opportunities along highway.

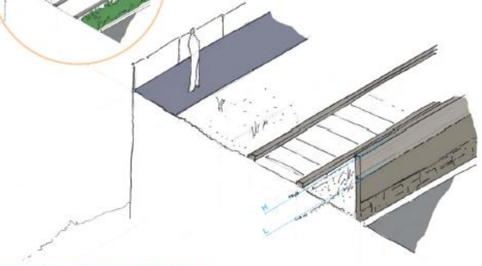
Consider contextual materials such as pennant stone walls, the Chocolate Walk paving and red brick coping and integration / relation of new materials.

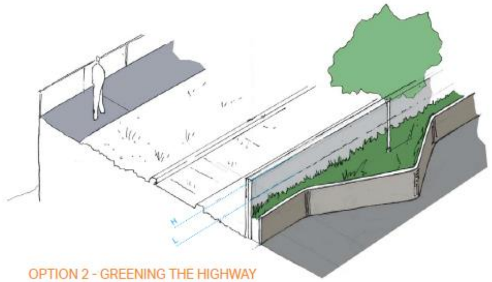
Explore inclusion / protection of heritage assets and potential new uses.

Greening the street and tree planting strategies to replace existing tree planting within narrow pavements.

Defence height up to 1.2m for low defences and 1.8m for high defences.

RIVERSIDE DEFENCE
An alternative would be to place the wall on the outer edge to include protection of heritage assets.



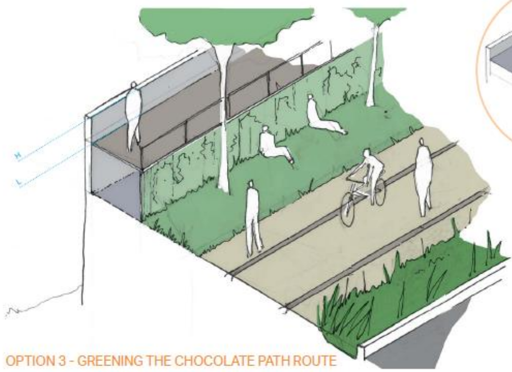


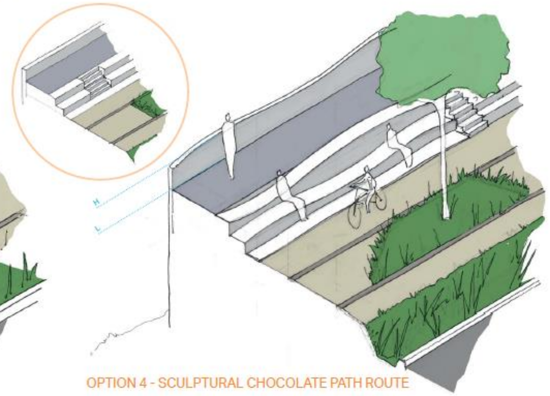
OPTION 1 - KERB LINE DEFENCE

This considers the proposed wall following the kerb line. This will be in addition to the current pennant stone defence wall as part of the MetroBus flood defence and further extend along. There are a number of options for the wall design to incorporate the pennant stone wall. This option however does not offer any protection of the heritage assets and segregates / isolates the chocolate path users with a high defence wall of 1.8m height. This design risks creating a built corridor that extentuates noise and pollution within the street environment.

OPTION 2 - GREENING THE HIGHWAY

Where highway space allows, such as along coach parking bays, linear planters green the street along the defence wall and create opportunity for green infrastructure. New tree planting could be used at regular intervals to replace existing trees within the opposite pathway which are poorly positioned and causing pavement degradation.





OPTION 3 - GREENING THE CHOCOLATE PATH ROUTE

The wall protects heritage assets and utilises the space with demountable panels. The Chocolate Path could be left in-situ with an elevated walkway enabling views. Could explore opportunities for green walls, tree planting and planted strips. The railway track could be infilled to create a wider pedestrian / cycle route away from the highway.

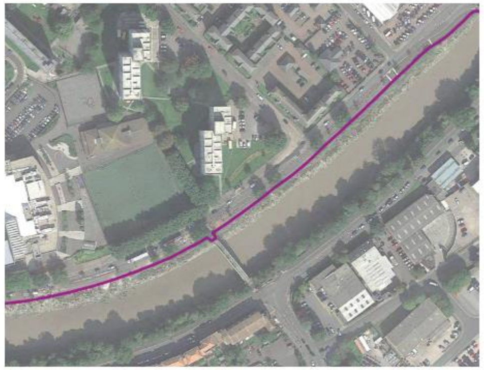
OPTION 4 - SCULPTURAL CHOCOLATE PATH ROUTE

This option offers a protective wall and elevated walkway. The Chocolate Path paviours could be relaid on this walkway and adjoin seating steps along the infilled railway track, a pedestrian / cycleway with opportunity for planted strips, tree planting and rain garden / attenuation ditch as SUDS to the highway.

AECOM

Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **2. Cumberland Road Concept Sketch Options**

C L A R E N C E   R O A D



Opportunities for a widened section build-out from the existing river wall of between 1-2 metres.

Constraints are existing highway and cycle lane, although options explore incorporation of the cycle way into the public realm.

Ground levels on Clarence Road vary from 10.1m to 7.6m.

Maximum wall height above ground level will be 2.05m for low defences and 2.7m for high defences.

Average wall height above ground level will be 1m for low defences and 1.65m for high defences.

Walls can be built initially to low defence level but capable of being raised to high defence level by using demountable defence wall or glass panels as an option to reduce scale of the highest wall sections.

This requires a defence and public realm adaptable to varying wall heights as and when required.

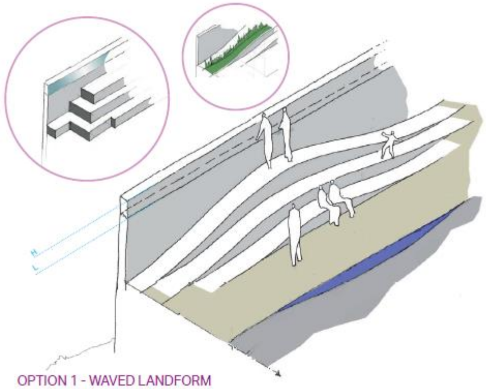
Utilise / maximise potential additional public realm space.

Reduce scale and visual impact of defence wall (2.7m maximum for high defence) by use of form, materials and planting.

Incorporate planting strategies to green the street.

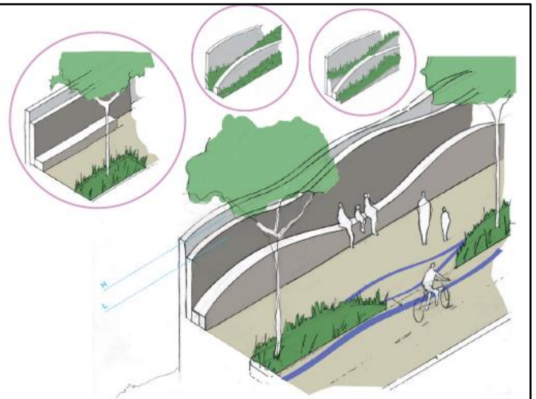
Potential for shrub planted bands, rain gardens, tree planting to replace existing trees and to increase future resilience.

There are a number of options available along Clarence Road due to variances of the wall heights and could include cantilevered viewing platforms and/or pods extruded from the flood wall as with the Bonded Warehouses section.



OPTION 1 - WAVED LANDFORM

This option explores the possibility of a waved landform feature that could incorporate seating walls and a viewing level. Variations on this could include planting strips and coloured surfacing.



OPTION 2 - WAVED WALL

The waved form incorporated into the flood defence wall steps out to create a 3-dimensional vertical feature that could include a seating wall. This could be mirrored on the river side face to reflect its feature on both sides of the wall and across the river. Other variations include raised planters and planting strips.

OPTION 3 - WAVED SURFACE FEATURES

A flowing surface treatment with defined seating places and planted beds meandering along the route. This offers rest and relief from the primary pathway route and offers a more relaxed option. This could contribute to a wider tree planting strategy, and / or rain garden opportunities.

OPTION 4 - GREENING THE CORRIDOR

A series of raised planter strips along a green wall incorporates tree planting and seating opportunities. The green wall could be pre-grown ivy fence screens tolerant of shade and / or climbing plants fixed to cable systems.

AECOM | Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **3. Clarence Road Concept Sketch Options**

THE ARENA SITE

Consider the redevelopment associated with the Arena, to include the proposed St. Phillips footbridge and future plaza space link from Albert Road.

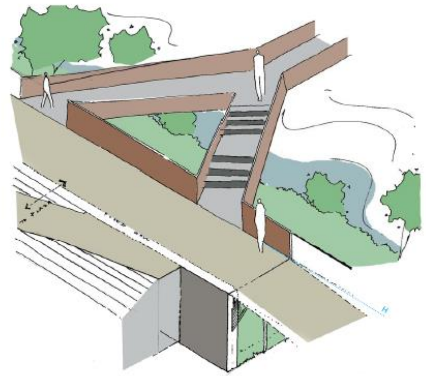
Continuation and link of the existing River Avon Walkway.

Defence height of 2.1m for low defences and 2.7m for high defences.

This nodal point which will connect the existing river walkway to future proposals. If this is to be a permanent access (i.e. above flood level) the platform will potentially be set at high defence level of 2.7m maximum.

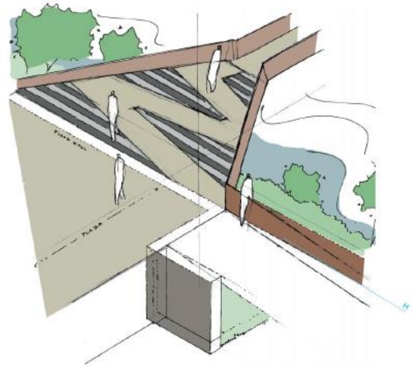
The proposed St. Phillips footbridge has separate ramp and steps leading to existing ground level. This proposal explores options to connect the proposed bridge and / or alternative solutions of its access.

The options allow flexibility to enable a cantilevered / raised platform deck at flood wall height level which can either continue along the Avon Walkway at raised level or ramp to existing ground level.



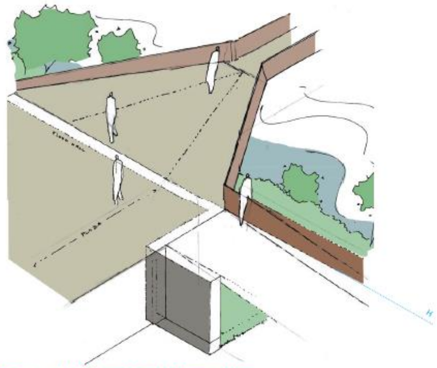
OPTION 1 - PLATFORM DECK TO FOOTBRIDGE

A cantilevered platform off the flood wall at full defence height of 2.7m high adjoins the footbridge steps and separate ramp to the future plaza space. The platform extends to the Avon walkway, with the options for ramping to existing ground level or suspended above as a cantilevered walkway.



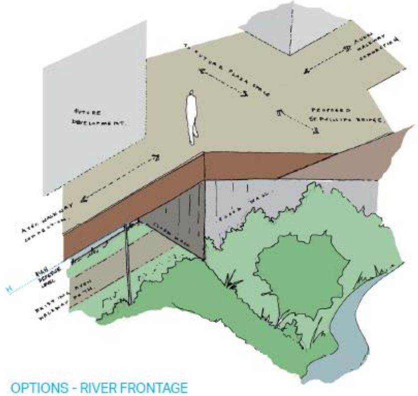
OPTION 2 - RAMP AND STEPS ACCESS TO FOOTBRIDGE

The steps and ramp feature (or 'stramp') joins directly to the Plaza space which extends over the existing Avon Walkway, making the space an integral part of the journey in all directions. This also connects the space with the River. The adjoining platform walkways have the option to be at level with the flood defence wall or ramp to existing ground levels.



OPTION 3 - RAMP ACCESS TO FOOTBRIDGE

As with option 2 but a simple ramp feature joins directly to the Plaza space which extends over the existing Avon Walkway, making the space an integral part of the journey in all directions, connecting the Plaza space with the River. The adjoining platform walkways have the option to be at level with the flood defence wall or ramp to existing ground levels.



OPTIONS - RIVER FRONTAGE

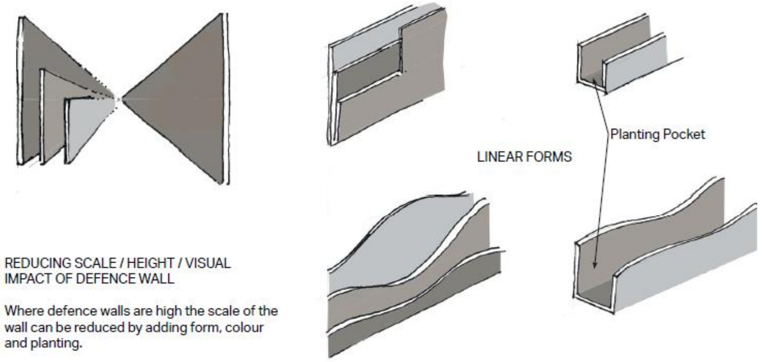
Consideration is given to the river frontage, its appearance and impact on the riverside edge. A raised walkway allows a void under the walkway and is allowed to flood, however, creates a void space which will naturally regenerate subject to light availability. A front facing flood wall creates a solid defence and support for the bridge structure but has a larger physical and visual impact.

AECOM | Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **4. The Arena Site Concept Sketch Options**

INTEGRATION / RELATION OF CONTEXTUAL AND NEW MATERIALS

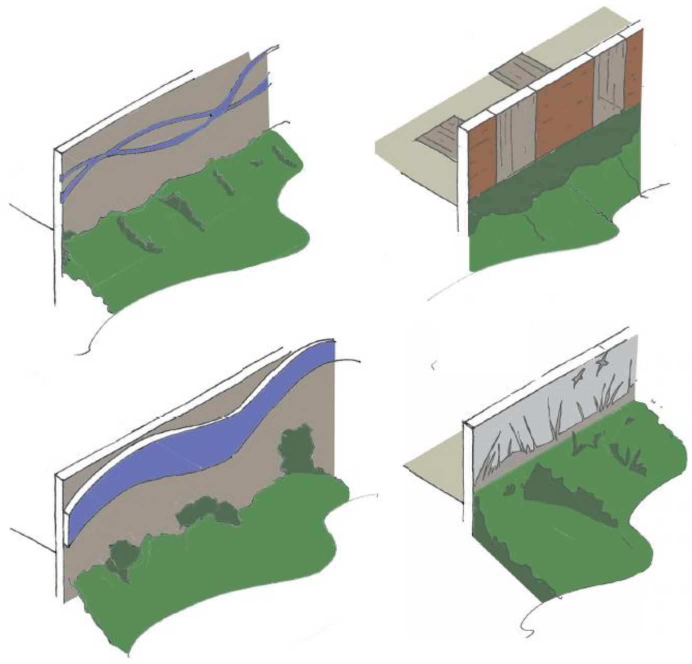
The project will explore how local vernacular materials can relate to new materials. The materials are required to be robust, cost effective and attractive. Special features and materials can be used to highlight intervention points along the route.

Form and materials create part of the legibility, language and comfortability of the 'greenway' route. There may be repetitions and/or subtle connections used in different ways.



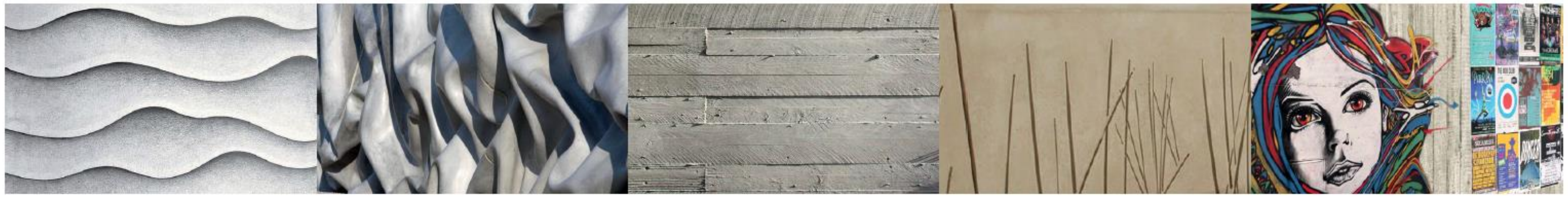
REDUCING SCALE / HEIGHT / VISUAL IMPACT OF DEFENCE WALL

Where defence walls are high the scale of the wall can be reduced by adding form, colour and planting.



MIRRORING THE EFFECT ON BOTH FACES OF THE DEFENCE WALL

The appearance on both faces of the wall can mirror the form, texture or colour.



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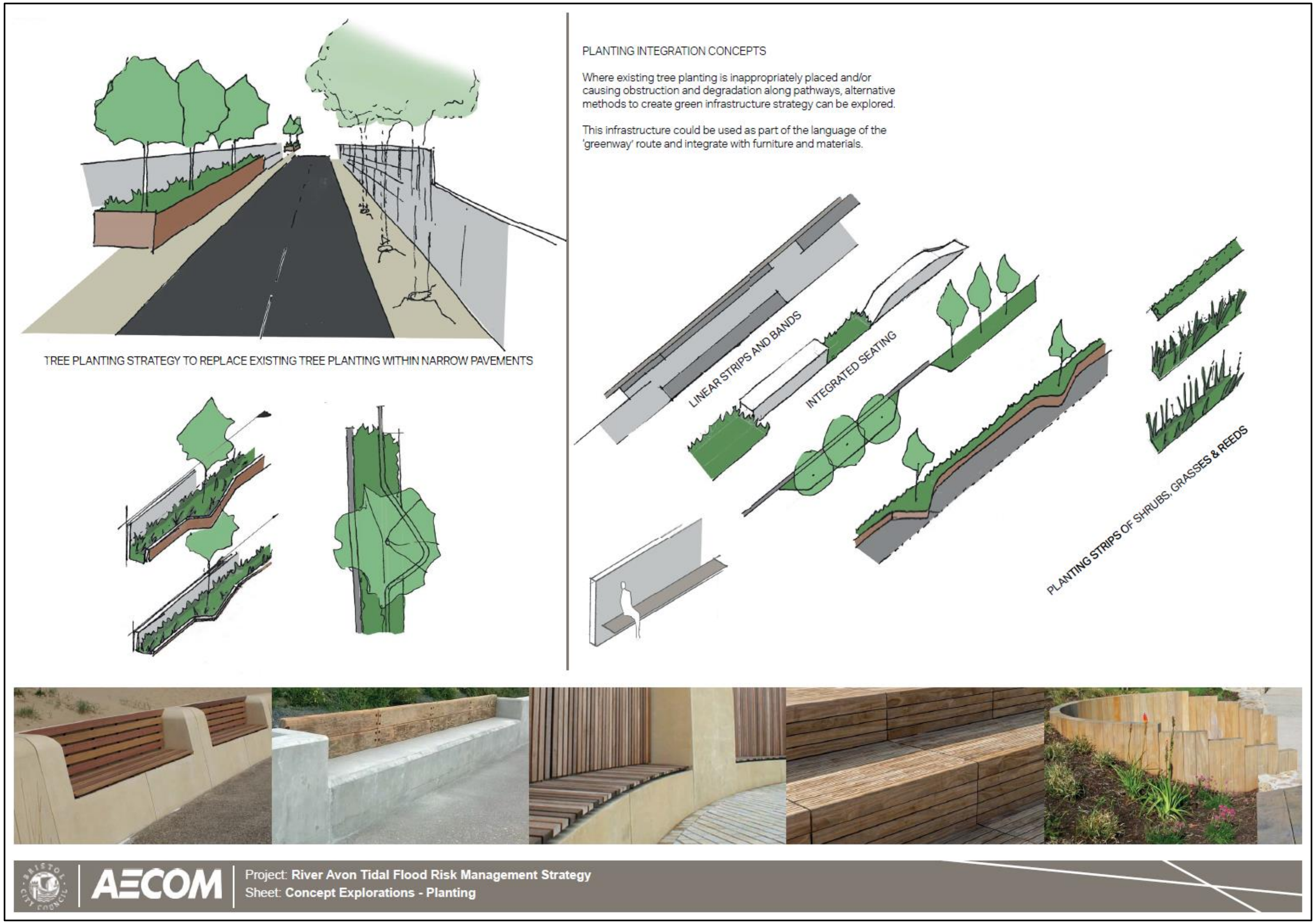
Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **Concept Explorations - Wall Form & Materials**


TREE PLANTING STRATEGY TO REPLACE EXISTING TREE PLANTING WITHIN NARROW PAVEMENTS
PLANTING INTEGRATION CONCEPTS
Where existing tree planting is inappropriately placed and/or causing obstruction and degradation along pathways, alternative methods to create green infrastructure strategy can be explored.
This infrastructure could be used as part of the language of the 'greenway' route and integrate with furniture and materials.
LINEAR STRIPS AND BANDS
INTEGRATED SEATING
PLANTING STRIPS OF SHRUBS, GRASSES & REEDS
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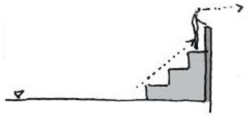
Project: River Avon Tidal Flood Risk Management Strategy
Sheet: Concept Explorations - Planting

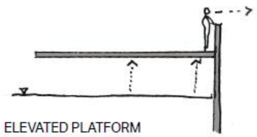
CONNECTING THE RIVER

The safety, access and comfortability for the users is to be considered. Issues of traffic, pollution, noise, access, isolation, legibility can be addressed. Explorations for connecting the user to the river will be explored.

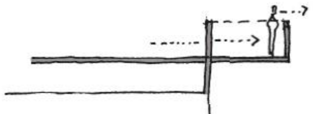
VISUAL ALLOWANCE CONSIDER VIEW ACCESS AT LOW AND HIGH DEFENCE LEVELS



SCULPUTURAL LANDFORM TO ALLOW VIEWS



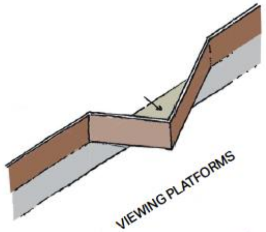
ELEVATED PLATFORM

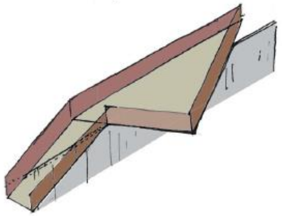


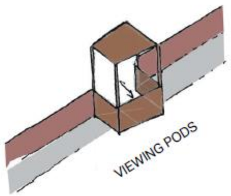
EXTENDED VIEWING PLATFORMS

PLATFORMS

Adaptability to change. Solutions need to be versatile and be adaptable.

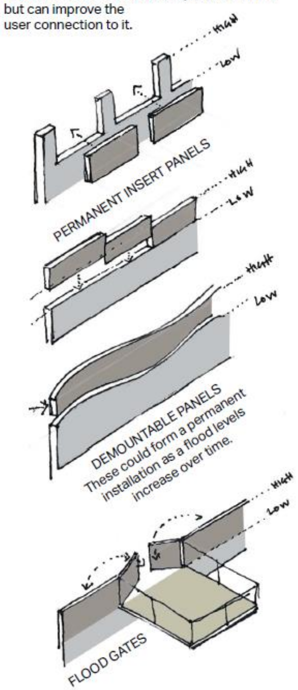






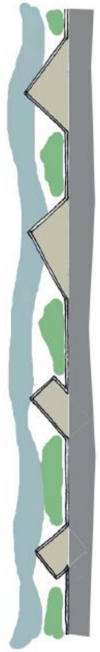
BARRIER RESILIENCE

Connections and relationship to the river. The flood defence seeks not to seperate the river but can improve the user connection to it.



DESIGN LANGUAGE

Platforms and/or pods can be used as part of the language of the route at key points to highlight views, points of interest and nature watching. They also offer rest points and interventions from the route.



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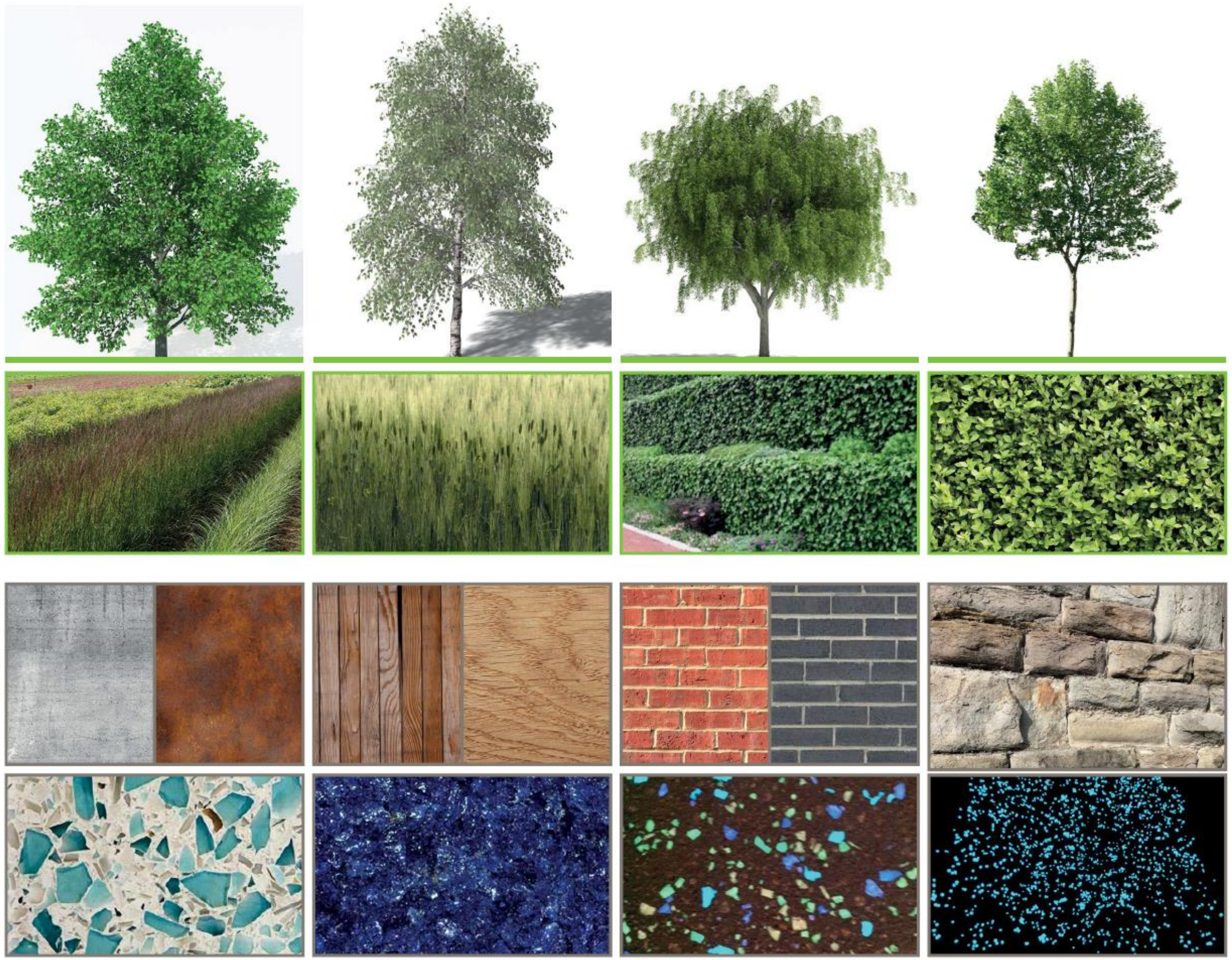
Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **Concept Explorations - Resilience & Connectivity**



PLANTING

PLANTING TO REFLECT RIPARIAN CHARACTER OF THE RIVER CORRIDOR:

- GRASSES
- GREEN-SCREENS / GREEN-WALLS
- TREE PLANTING SUCH AS ALDER, BIRCH AND WILLOW

MATERIALS

- LOCAL CONTEXTUAL MATERIALS SUCH AS PENNANT STONE, RED AND BLACK BRICK
- CONCRETE
- CORTEN STEEL
- TIMBER
- AGGREGATES
- RECYCLED MATERIALS SUCH AS RESIN BOUND GLASS
- LUMINESCENT AGGREGATES OR PEBBLES IN WALLS AND PAVING

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Project: **River Avon Tidal Flood Risk Management Strategy**
Sheet: **Materials and Elements**

Appendix G – Glossary of Technical Terms

1 in 200 (0.5% AEP) – a water level event that would have a 0.5% probability of occurring in any one year

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

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.

PLP – Property Level Protection, measures applied to individual properties to provide flood proofing

Outline Business Case (OBC) – Document format for submittal to Environment Agency to secure GiA funding of a scheme

FCERM-AG – Flood and Coastal Erosion Risk Management Appraisal Guidance

GiA – Grant in Aid

LPRG – the Environment Agency's Large Project Review Group

EIA – Environmental Impact Assessment

HRA – Habitat Regulations Assessment

WFD – Water Framework Directive

SEA – Strategic Environmental Assessment