

Bristol City Council
Bristol Flood Strategy
Updates to Proposed Defences

Issue

Issue | 14/09/2020

This report takes into account the particular instructions and requirements of our client.

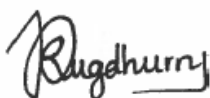











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References

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- [2] Arup, “Bristol FRM Strategy, Overview of flood modelling”.
- [3] Arup, “Bristol FRM Strategy; Detriment Mitigation option Development,” 2020.
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- [7] Arup, “Review of BCC Asset Inspection Data in relation to proposed defences,” 2020.
- [8] Arup, “High level review of AECOM structural proposals for significant assumptions or opportunities that may impact on defence structures strategy overall viability,” 2018.
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1 Introduction

Arup has been commissioned by Bristol City Council (BCC) to update the Strategic Outline Case (SOC) for Bristol Flood Risk Management that was undertaken by AECOM in 2017 [1]. Arup has carried out additional hydraulic modelling in 2019-2020 which requires updates to the proposed defences costing that were identified in the previous AECOM study in 2017.

The purpose of this report is to:

- Summarise the proposed defences by AECOM
- Outline the changes to proposed defences required following further modelling work by Arup
- Set out where new defences are required that were not previously part of the AECOM strategy
- Outline the detriment mitigation measures which are identified as additional defences required to prevent flooding detriment to other areas due to the construction of the defences

Approach to updating the SOC

As a result of the revised hydraulic modelling and increased Project extents, it has not been possible to undertake this exercise without having to revisit the engineering logic and costing approach based on the scale and the extent of the works, as well as the feasibility of the original approach.

It was agreed for the outcome of additional engineering and costing services to be used to inform the SOC. The supporting information is not provided. This report sets out the risks and the differences that revisiting the hydraulic modelling/AECOM outputs causes but not the detail of proposed engineering changes. The costing shall summarise the costs for each reach that is used in the cost benefit analysis. Information on the key assumptions used is also be provided. Information on the methodology and assumptions for costing and the rates used is also included but take-offs or quantities of materials are excluded at this stage.

The SOC references the updated extents of defences as per the modelling reports [2] [3]. No updated drawings or details of amendment to engineering expectations will be undertaken other than typical detriment mitigation defences. The drawings covering the interface with Bristol Temple Quarter are in Appendix I.

Approach to costing of defences

The standard of protection provided by this strategy considers 2 epochs – 2065 and 2125. To develop the costing of the defences, the strategy assumes an adaptive approach to defences which means:

- a) An initial construction period of 2023-2025 (referred to as 2020s) to construct defences to the Flood and Coastal Erosion Risk Management (FCERM) 2065 standard of protection (SoP)

- b) Further increases to protection levels constructed in 2065 to a 2125 standard of protection (SoP).

This corresponds to the ‘low’ and ‘high’ defences from the AECOM study.

For areas identified for future development, also called ‘masterplanning areas’, around Entrance Lock / Western Harbour and Bristol Temple Quarter / St. Philips Marsh, the defences have been designed for National Planning Policy Framework (NPPF) standard of protection for the highest possible defence height.

The detriment assessment and development of detriment mitigation measures is intended to ensure the final Strategy option fulfils Flood Risk Assessment (FRA) requirements and that the scheme can be consented by the Environmental Agency (EA). Given the focus of detriment assessment is on the FRA requirements, all model simulations undertaken to assess detriment, and subsequently to develop and test detriment mitigation options, use the NPPF climate change allowances as opposed to the FCERM allowances.

For flood defences that are designed to provide a given SoP to receptors behind the defence, a freeboard allowance should be incorporated into the designed flood defence levels to manage the uncertainty in modelled water levels and physical processes such as waves. This has been assumed for the costing of the flood defences. However, where the flood defence is used purely for managing detriment as opposed to providing a given SoP to properties, a freeboard allowance is not strictly required. Therefore, for costing of the detriment mitigations, the higher of the FCERM with freeboard and NPPF without freeboard flood levels have been assumed.

Public realm enhancement

The costing of the defences also considered different levels of public realm enhancement:

- a) *Low public realm rate*, defined as alterations to general layout, use of basic materials, limited interventions
- b) *High public realm rate*, defined as alterations to general layout, creation of extent of public realm, seating, lighting, tree planting and Sustainable Drainage Systems (SUDS).

The cost estimation for the two levels of public realm enhancement is based on costing of recently completed schemes in the UK. The information has been adjusted to suit the local Bristol market. In 2018 Balfour Beatty completed an Interim Feasibility Report and provided initial commentary on cost estimates, including placemaking rates which have been compared. [4].

In general, a low public realm rate is assumed everywhere except on Reach 1 (section 1-8) at Entrance Lock/ The Knuckle where a “high level” of public realm rate is assumed to be required to accommodate the integration of defences into the public realm for consenting. The costing scenarios presented in Appendix D include scenario 8C_B (a variation of scenario 8C) with high public realm rate everywhere for comparison purposes.

Additional detail on public realm opportunities for some of the areas is available in the Placemaking Opportunities Report [5].

Maintenance Costs

The annual maintenance costs of the proposed defences have been calculated based on the EA 2015 Cost estimation for fluvial defences report (SC080039/R2) and uplifted to 2020 costs. A 30% optimism bias has been added to the cost.

The approach to calculate the annual operational and maintenance costs for the stop gates at Entrance Lock and Netham are based on cost information from BCC and the previous study for the deployment of the gates. An allowance for the maintenance of the existing defences has been assumed as per the previous study. All costs have been updated to 2020 rates.

This report also refers to harbour asset inspection data received in January 2020 from BCC [6, 7] and a structural review of the AECOM defences carried out by Arup in 2018 [8].

Further details of the defences proposed by AECOM are available in Appendices C and D of AECOM's Strategic Outline Case Report [1].

2 Updates to Flood Defences

2.1 Reach 1 – Entrance Lock / Western Harbour

2.1.1 Summary of AECOM proposal [1]

This 912m-long reach was proposed to run from Hotwells Road at the downstream end, around Spike Island (the Knuckle) and along the North bank of the Avon towards and tie into Cumberland Road (Reach 2).

A total of 218m of reinforced concrete floodwall and 378m of sheet pile floodwall were proposed, with associated ramps and floodgates where required.

A new flood gate and access ramp was also proposed for the upstream lock gate of Entrance Lock and the lock gate itself was to be replaced with new 9.5m-high, 22m-wide gates.

Resilience measures in the form of Property Level Protection were proposed for two Hydraulic Power Units (HPU) and the Harbour Master's office.

The following existing structures were proposed to be used as defences:

- Brunel dam (to be raised with mass concrete and sluice gates decommissioned)
- Existing Brunel Way/A3029 highway and bridge abutments
- Existing metrobus wall to be raised for the low defence (then replaced for high defences)

2.1.2 Proposed changes

Further modelling work has shown that the reach needs to be extended to a total of 1150m. For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the NPPF 2125 SoP has been assumed for costing.

To meet the NPPF 2125 SoP, the defences need to be increased by an average of 2.75m relative to the existing ground levels. The replacement of the lock gate and raising of Brunel dam have been assumed to be constructed in the 2020s to provide the NPPF 2125 SoP, due to complexity of phasing the works.

During the asset inspections in January 2020, a partial collapse of a heavily vegetated wall (NCN 02) [3, 4] was noticed. The wall is at the downstream end of Spike Island, adjacent to the slipway down from Brunel Way. In this area, it is likely that the raised road itself will provide the defence height, and therefore the wall at NCN 02 will not affect the works. If new defences were to be constructed on this alignment, it is likely that the existing wall could not be relied upon for support.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- Cost uncertainties of maintaining a navigable channel during lock gate replacement works.
- Brunel Dam and the steel pedestrian bridge above the dam are both Grade II listed structures. Consultation with heritage bodies should be undertaken as the ability to upgrade these structures to act as flood defences can greatly impact the costs.
- Costs could vary significantly due to lack of ground investigation information for the foundations of the defences and the raising of Brunel Dam. There is a significant risk of poor ground conditions near the historic riverbed and peat has been identified from existing ground investigation information which may lead to larger foundations than the current assumptions made in costing.
- Road raising or flood gate across the A4 will require the associated safety protocols/signage for operation.
- Access for construction around the harbour is likely to be complex.
- Construction of the floodwall along the river bank upstream of Avon Bridge may need work to stabilise the bank in the temporary case.
- Western Harbour has been identified as strategic growth and regeneration area in the Bristol Local Plan Review 2018 and this was consulted on in 2019. The project is still in the early scoping stages and a masterplan for the area has yet to be developed. The progress to date has included a Transport Feasibility Study and some early engagement on findings. Currently Bristol City Council is undertaking further engagement with stakeholders and communities to understand, capture and feed in views for the area before commencing any further works. The AECOM SOC [1] assumed the curved highway abutment is to be used as the defence. Whilst many highway reconfiguration options consider removing the highway abutment, a comparable structure in terms of flood containment has been assumed for costing.
- This area is a conservation area, has landscape sensitivities and is the gateway to the city bringing complexities that may vary costs.
- Interface with the low Ashton Avenue Bridge, may require further works to provide flood protection.

Opportunities

- Incorporation of features in the defences and use of historic structures to improve public realm and heritage value.
- Careful consideration of foundations to reduce overall cost of defences.

- This reach forms part of the Western Harbour character area and has been identified with placemaking opportunities, further details are provided in the Placemaking Opportunities Report [5].

2.2 Reach 2 – Cumberland Road

2.2.1 Summary of AECOM proposal [1]

This 635m long reach was proposed by AECOM to include raising the existing wall, which was then proposed to be replaced by a reinforced concrete floodwall in 2065 along the same alignment. The extent of the wall raising, and new flood defence height reduced as the ground level increases towards the downstream end.

2.2.2 Proposed changes

Further modelling has shown that the reach needs to be extended to a total of 850m. For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the FCERM 2125 SoP has been assumed for costing.

Based on the review of the Chocolate Path Remedial Works information sent by Bristol City Council [9], [10] we conclude that new works being carried out in the area to address Chocolate Path failures will provide foundations suitable for:

- a) the set-back wall to be raised to the FCERM 2065 SoP in the 2020s
- b) then raised again in 2065 to the FCERM 2125 SoP.

So, foundations for this 113m-long section have not been costed and raising of the floodwall has been assumed for costing.

For the rest of this reach, raising the existing Metrobus wall to the FCERM 2065 SoP is not considered feasible due to the required 0.9m rise. Therefore, similar cost to the Chocolate Path remedial works [9], [10] have been included.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- It is noted that a major collapse of Cumberland Road occurred in January 2020. The works to address this will also have an impact on the detailed design of proposals in this area.
- From the asset inspection in January 2020, a bridge supporting the chocolate path (NCN03a) [3, 4] is suffering from severe corrosion with significant weaknesses along the main girder at the bearing and stiffener locations. The bridge is adjacent to Cumberland Road and just upstream of Ashton Avenue Bridge. A full structural survey has been recommended as part of the condition survey before the bridge is confirmed suitable for vehicles. As this bridge is directly supporting a section of the Chocolate Path, flood defence works in this area are likely to impact the bridge. Therefore, construction works cannot be commenced until the bridge has been structurally assessed and repaired or replaced.

- The structures review in April 2018 [8] found there to be a high risk of cost increase due to methods required for the contiguous piled walls (river working or full road closure and interaction with heritage railway).
- The type and size of foundations will govern the size of construction plant required and therefore impact the stability of the slope/bank during construction. The impact of construction surcharge on the bank stability and the design needs to be carefully evaluated at later designs stages.
- Temporary and permanent construction including piling onto the riverbank may have negative environmental and ecological impacts and are anticipated to require road closures.
- The Chocolate Path remains the main pedestrian access path along the River Avon, however, road raising on the landside of the new wall to reduce the visual impact may be required.
- Construction details of the existing retaining riparian wall are unknown, with unrecorded buttresses encountered during the adjacent Chocolate Path Remedial Works.
- This area is a conservation area, has landscape sensitivities and is the gateway to the city bringing complexities that may vary costs.
- The defences are proposed across the alignment of the former River Avon natural channel. Costs could vary significantly due to lack of ground investigation information for the foundations of the defences. The adjacent Chocolate Path Remedial Works pile design was affected by aggressive ground conditions in the tidal flat deposits. The harbour railway drainage has failed in places, due to sedimentation. This increases the risk of bank slippage/instability, particularly at times of tidal surge and with the harbour railway retaining structure in front of the highway retaining structure.
- The Cumberland Road flood wall (constructed between the highway and the railway) is a flood defence. Temporary works will need to ensure no reduction in flood defence during the construction phase.
- The path is on the riverside of the flood defence. A combination of ramps and possibly gates will be required to provide suitable access from Cumberland Road.

Opportunities

- Re-arranging cycling and walking paths on the river side has been considered in line with the 'Wester Corridor' character area intervention typology as set out in the Placemaking Opportunities Report [5].
- Costs could vary significantly due to lack of ground investigation information for the foundations of the defences. There is a significant risk of poor ground conditions near the historic riverbed and peat has been identified from existing ground investigation information which has been allowed for in the design but if not realised may lead to a cost saving.

2.3 Reach 3 – Cumberland Rd East Defence

2.3.1 Summary of AECOM proposal [1]

A 3m floodgate was proposed across the railway: underneath the Cumberland Road bridge with a flood wall on the downstream end and ramps on the upstream end which extended this reach to 16m in total.

2.3.2 Proposed changes

Additional modelling has shown that the wall height needs to be a maximum of 2m. It is assumed that the floodgate and ramps are constructed to the FCERM 2125 SoP in the 2020s and an adaptive approach for the floodwall has been assumed for costing.

As this reach is now directly connected with Reach 2, the downstream flood wall will tie directly into Reach 2 walls.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- The structures review in April 2018 [8] found there was insignificant risk of potential variation, although interactions with the heritage railway may cause cost variations.
- Approvals by Office of Rail and Road (ORR).
- This area is a conservation area and has landscape sensitivities bringing complexities that may vary costs.

Opportunities

- No major opportunities have been identified.

2.4 Reach 4 – Commercial Rd Defences and Bathurst Dam

2.4.1 Summary of AECOM proposal [1]

The previous proposal was a 298m reinforced concrete flood wall on contiguous piles. The wall was set into the riverbank from Bathurst Dam at the downstream end to tie into higher ground further upstream on Commercial Road. Bathurst Dam itself was proposed to be raised and thickened using mass concrete dowelled into the existing structure.

It is noted that the proposals for this area were amended in the previous study to consider the new MetroBus road bridge. This was mainly a change of alignment to follow the new road.

2.4.2 Proposed changes

Additional modelling has shown that the defences need to be extended upstream of the original reach to a total length of 310m. For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the NPPF 2125 SoP has been assumed for costing. An exception is the raising of Bathurst Dam, which is assumed to be constructed to the FCERM 2125 SoP in the 2020s.

Bathurst Dam is proposed to be raised and thickened using mass concrete dowelled into the existing structure in the 2020s.

A small section of reinforced concrete floodwall downstream of the dam to tie into God's Garden is also proposed.

To meet the FCERM 2125 SoP, the defences need to be increased to an average height of 2m relative to the existing ground levels.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- Limited access to raise and encase Bathurst Dam in mass concrete due to proximity to the new Metrobus road bridge.
- The land to the South East of Bathurst Dam is privately owned and the landowner is considered a key stakeholder in terms of interest and influence on the project. We recommend consultation with the landowner at the next stage.
- The ground around Bathurst Dam could be contaminated due to nearby historic structures. A high coal risk area, according to the Coal Authority database, is also nearby. Drilling/digging may impact into unknown coal mines, causing localised ground collapse.
- Construction details of the existing wall on Commercial Road are unknown.

- The temporary and permanent construction, including piling onto the riverbank, may have negative environmental and ecological impacts and are anticipated to require road closures.
- During the asset inspections in January 2020, a timber retaining wall (NCN20) [3, 4] was observed as collapsed or deformed in sections, causing it to lean into the river. The wall is just upstream of the Bathurst Basin on the North bank of the New Cut. It is likely that the detailed design of flood defences in this location will not consider any support provided by the timber retaining wall. The condition of this asset will have little effect on the strategy defences.
- This area is a conservation area and has landscape sensitivities bringing complexities that may vary costs. The dockside walls are listed structures.

Opportunities

- From the structures review in April 2018 [8], alternative options to repair/rebuild the existing riparian wall with a new flood wall on top were investigated. There is an opportunity to carry out detailed structural and geotechnical assessment on the existing wall to inform its use as defences.
- This reach forms part of the Western Corridor character area and has been identified with placemaking opportunities, further details are provided in the Placemaking Opportunities Report [5].

2.5 Reach 5 – Clarence Road Defences

2.5.1 Summary of AECOM proposal [1]

A contiguous piled flood wall of length 623m was proposed to run along Clarence Road. Langton St Bridge (footbridge) abutment was used as part of the defence where required. At the downstream edge the wall tied into high ground. At the upstream end the wall tied in with the footbridge and road bridge abutments.

2.5.2 Proposed changes

Further modelling work has shown that the length of wall needs to be marginally shorter, at 590m. For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the FCERM 2125 SoP has been assumed for costing.

To meet the FCERM 2125 SoP, the defences need to be increased to a maximum average height of 2m relative to the existing ground levels.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- Construction details of the existing wall on Clarence Road are not known. There was a failure of a section of Clarence Road wall due to a 2014 tidal surge which has been repaired.
- Lack of topography data at Clarence Road limits the assessment of the encroachment of the cantilever wall onto the riverbank.
- Temporary and permanent construction including piling onto the riverbank may have negative environmental and ecological impacts and are anticipated to require road closures.
- Further structural and geotechnical investigations will be required to establish the feasibility of using Langton Street footbridge abutment structure as the defence to meet the 2125 SoP and to identify any required repair or modification works.
- This area is a conservation area and has landscape sensitivities bringing complexities that may vary costs. Proposals would require removal of a mature line of trees.
- The type and size of foundations will govern the size of construction plant required and therefore impact the stability of the slope/bank during construction. The impact of construction surcharge on the bank stability and the design needs to be carefully evaluated at later designs stages. If construction is undertaken from Clarence Road, road closures will be required.

Opportunities

- From the structures review in April 2018 [8], alternative options to repair/rebuild the existing riparian wall with a new flood wall on top were investigated. There is an opportunity to carry out detailed structural and geotechnical assessment on the wall to determine its suitability as part of the defences.

2.6 Reach 6 – Cattle Market Rd Defences

2.6.1 Summary of AECOM proposal [1]

A reinforced concrete flood wall with piled foundation was proposed for this 190m long reach which tied into the rail bridge abutments. The downstream edge of the wall tied into high ground and the upstream edge into the Bristol Arena road bridge defence.

2.6.2 Proposed Changes

Further modelling has shown that to meet the FCERM 2125 SoP, the defences need to be increased to an average height of 3.5m relative to existing ground levels. A small options study has been undertaken to investigate the viability of installing a wall in this reach, see Eastern Corridor Technical Note [11]. This has been used as the basis for the costing.

An adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the FCERM 2125 SoP has been assumed for the costing.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- All foundations have been costed assuming that they are founded on competent rock. The location of competent bedrock is uncertain and to be confirmed in the next stages following ground investigations. This may lead to bigger foundations and alternative piling techniques.
- The strategy assumes the existing railway bridge abutment acts as a flood defence, however, the residual life of this structure is not known. Further investigation into the suitability of this structure for flood defences to 2125 should be undertaken, including consultation with the asset owner.
- Interactions with Network Rail will need to be managed for works interfacing with the rail infrastructure.
- Construction details of the existing wall are not known.

Opportunities

- It was noted in the April 2018 structures review [8] that the omission of piled foundations could be investigated at detailed design, which would give significant cost savings. However, as this is currently unknown, the piles are to be included at this stage.
- This reach forms part of the Western Corridor and Eastern Corridor character areas and has been identified with placemaking opportunities, refer to the Placemaking Opportunities Report [5].

- The proposed riverside walls prevent inundation of the Cattlemarket Road underpass. However, some adjacent buildings have an elevated threshold containing overtopping to the local area. Should the Post Office site redevelopment address the flood pathway to the Bristol Temple Meads railway station underpass, a lower SoP may be able to be accommodated.

2.7 Reach 7 – Bristol temple Quarter / St. Philips Marsh

2.7.1 Summary of AECOM proposal [1]

A total of 1510m of defences from Bristol Arena road bridge (tying in to reach 6) at the downstream end to Sparke Evans park at the upstream end was proposed.

The form of defences varied along the reach.

- North – mostly sheet piled flood wall.
- Centre – mostly sheet piled wall, also resilience measures to existing buildings.
- South – RC walls, plus flood defences to existing buildings. Sheet piled wall assumed for high defences.
- Sparke Evans park – embankment.

For low defences, a sheet piled defence was assumed to be installed along the full length from Brock's Bridge to Sparke Evans park with no cost or constraints of land assembly. Buildings were assumed to be flood proofed including installation of flood doors, air brick covers and where appropriate tanking and structural support. Reinforced concrete cantilever walls were proposed to fill between the buildings. The high defences in this area are assumed to be a new sheet piled defence installed during future development. This area covers approximately 700m of the reach.

The flood wall tied into: ramped access to new bridge; ramps for railway bridge; abutment of road bridge; existing buildings or future redevelopment; embankments (~150m); and the boundary wall.

2.7.2 Proposed changes

This reach protects the Bristol Temple Quarter masterplanning area, and as such the area is likely to be significantly developed over the appraisal/design period. Therefore, for this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP has been assumed for the costing. It is anticipated that as the Bristol Temple Quarter area is developed, the new developments will provide flood defences to NPPF 2125 levels. If by 2065 new defences have not been built by developers, additional defences will be required.

To meet the FCERM 2065 SoP, the defences need to be increased to a maximum average of 1.5m relative to the existing ground levels.

The narrow open river corridor is flanked by many existing third-party riverside industrial properties and compounds. The landownership extent of several properties extends beyond their physical boundary to the river's edge.

A small options study has been undertaken to investigate the viability of installing a piled wall in this reach, see Eastern Corridor Technical Note [11]. This has been

used as the basis for the costing. This avoids the need for widespread dependency on land assembly. To ensure the strategy default option is consentable, it has been assumed that the piled wall includes a cantilevered 3m path to maintain a serviceable foot or cycle way. A low vibration drilling technique has been assumed to minimise disturbance to the existing structures on the landside.

The reach is adjacent to and interfaces with the Bristol Temple Quarter, an area identified as strategic growth and regeneration area in the Bristol Local Plan Review 2018, and part of the Bristol Temple Quarter Enterprise Zone extension. A Development Framework for the area is under preparation. The ambition is for future development to integrate the flood defence proposals in a sympathetic way and maximise the potential of creating a widened green corridor and significant recreational asset for the development and the wider city.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- Access to the St. Philips Marsh River path is restricted with approximately 30% of the footpath with a path width of less than the Sustrans Design Guidance minimum recommendation of 2.5m, going down to 1.5m in some sections. This limits the construction plants and piling rigs that can be used for construction which will limit the size and type of foundations that can be installed.
- As discussed in the Preliminary sizing of flood defence at Eastern Corridor Technical Note [11], the riverbank stability needs to be maintained in the temporary and permanent stages. There is a risk that further design may result in bigger piles that may not be able to be built from landside due to restrictions on allowable construction surcharge.
- There are numerous existing structures on the landward side of the footpath, details of which are unknown. The existing structures and foundations may be constraints to the new wall as the risk of any damage or disturbance to these structures could result in higher project costs related to additional temporary works.
- The floodwall may require temporary and permanent construction including piling onto the riverbank which may have negative environmental and ecological impacts.
- A large section of this reach is privately owned, as shown on the Bristol New Cut Land Ownership maps [12]. We recommend consultation with the landowners at the next stage as this will influence the design of the defences and costs.
- The cantilevered path is on the riverside of the flood defence. A combination of ramps and possibly gates will be required to provide suitable access from the hinterland.

- The Environment Agency installed a low series of bunds/walls in 1981 to reduce the chance of flooding. The condition of these structures and ability to maintain them is poor. The proposals will need to address this.

Opportunities

- This reach forms part of the Eastern Corridor character area and has been identified with placemaking opportunities, further details are provided in the Placemaking Opportunities Report [5].

2.8 Reach 8 – Netham Defences

2.8.1 Summary of AECOM proposal [1]

The proposed flood wall length was 715m. The wall was proposed to extend from the Avon rail bridge along the North bank of the Avon, where it was proposed to raise the existing sheet piles with a concrete pile cap for the low defences. For high defences, a new contiguous bored pile wall was proposed. Along Feeder Road, the existing boundary road wall was to be replaced with a concrete gravity wall on the same alignment.

Tie-ins to the derelict bridge next to the Avon rail bridge, and some raising of Feeder Road, was also suggested. This reach also proposed modifications to the outfall from Avonside Road and the sluice structure. Some vehicle and pedestrian routes were either moved or raised.

A new 11m wide, 7m high lock gate, set approximately 200m downstream of the current lock and Netham Road crossing, was proposed.

2.8.2 Proposed changes

For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the FCERM 2125 SoP has been assumed for the costing.

Further modelling work has shown that to meet the FCERM 2125 SoP, the floodwall needs to be higher by an average height of 2m relative to the existing ground levels.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- At Netham lock, there are existing buried structures along Feeder Road, details of which are unknown.
- There is a risk of soft ground at Netham Lock, it is assumed that sheet piles can be driven through the existing ground profile since the existing defences are also a sheet piled wall. Further ground investigation should be carried out to determine the feasibility of sheet piled walls to current design codes at later design stages.
- Vibration from sheet piling may have negative environmental and health & safety impacts during construction.
- The River Floodgate structure will be unique, and the design will have to be undertaken carefully to avoid overcomplication.
- Construction details of the existing wall is not known.
- This area is a conservation area and has landscape sensitivities bringing complexities that may vary costs.

Opportunities

- This reach forms part of the Netham Lock character area and has been identified with placemaking opportunities, further details are provided in the Placemaking Opportunities Report [5]

3 New defence locations

This section outlines flood defences proposed in new areas that did not form part of the flood defence proposed by AECOM. Some of these defences were proposed by AECOM as detriment mitigation measures but were not developed to the same extent as the previously proposed defences.

For ease of reference we have defined these additional areas as new reaches.

3.1 Reach 10 – Bower Ashton

In this area, AECOM proposed a raised bank approximately 480m long with a crest level matching the design level for high defences on the north bank and an average height of the defence of approximately 1.40m [13]. Further modelling has shown that defences need to be considerably longer, to a total of 955m. For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the FCERM 2125 SoP has been assumed for the costing.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- The ground level is highly variable: due to insufficient topography information at this stage there is a risk of insufficient space to build embankments to the required SoP.
- The railway running parallel to this reach acts as a conduit which may cause flooding to adjacent properties during flooding events.
- Environmental risk as construction may require many trees to be cleared.
- This area is a conservation area and has landscape sensitivities bringing complexities that may vary costs.
- Interface with the low Ashton Avenue Bridge, may require further works to provide flood protection.

Opportunities

- Potential alignment with emerging Western Harbour proposals, refer to section 2.1.2.
- Potential to enhance public open space amenity and viewing of gorge.

3.2 Reach 13 – Totterdown Centre (South)

In this area, AECOM proposed 200m of ‘additional walls’ as detriment mitigation [1].

Further modelling has shown that the new proposed defences need to be considerably longer, to a total of 640m long. They extend upstream from Totterdown Bridge the end of the Paintworks development. For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the FCERM 2125 SoP has been assumed for the costing.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- The structural integrity and residual life of the existing gabion walls at the Paintworks development are unknown and will need to be investigated further as they may not be structurally sound to be used as defences for the 2125 SoP. There may be additional costs associated with strengthening the gabion wall. The structural form assumed may require updating to suit public realm requirements with cost implications.
- It was noted on the harbour condition survey that there is some damage to the existing wall [6, 7]. As this wall is to be relied upon for this strategy, survey and / or repair work should be carried out.
- From the asset inspection in January 2020, deformed blockwork was noticed on the top of the capping beam (asset NCS41) [6, 7] at the upstream end of the central trading estate. This is causing cracking in the blockwork at the end of these sections. The existing wall is likely to be utilised as part of the strategy, and it may require raising in the 2060s to account for sea level rise. An assessment and suitable repairs to the wall are therefore required to ensure they operate effectively.
- There are existing private defences in place along this reach, with unusual riverfront flood gates for visual connectivity.

Opportunities

- The road (A4) behind the 150m downstream end of this reach is at a higher level than the flood defence levels, therefore there is an opportunity to review the protection required for this section along with future developments in this area.
- Some of the properties are from recent development; they are designed with flood risk resilience measures such as flood tolerant ground floors and/or raised thresholds to current standards.

3.3 Reach 14 – Feeder Road

Further modelling has shown that flood defences of a total length of 1133m are required along Feeder Road extending from near the rail bridge over the Floating Harbour and Cattle Market Road to just beyond St Philip's Causeway.

For this reach, an adaptive approach to construct defences in the 2020s to the FCERM 2065 SoP and to raise the defences in 2065 to the NPPF 2125 SoP has been assumed for the costing.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- Interface with Bristol University Campus developments may lead to additional costs.
- At the downstream (southern) end of Feeder road, there are existing historic structures which may be impacted by the works.
- There are three service bridges and the St Philips causeway bridge along Feeder road and the interfaces of the new wall and piling activities with these existing structures will need to be considered at a future stage.
- The riverbank at Feeder road is used by the public and therefore public engagement may alter the scheme, adding costs.
- It was noted on the harbour condition survey that there is some damage to the existing retaining wall. The construction details of the existing wall are unknown.

Opportunities

- The reach is also within and interfaces with the Bristol Temple Quarter, an area identified as strategic growth and regeneration area in the Bristol Local Plan Review 2018. A Development Framework for the area is under preparation. There is an opportunity for future development to integrate the flood defence proposals.

3.4 Reach 15 – St Anne’s (North Bank)

Further modelling has shown that new defences are required upstream of Netham Weir on the North bank: a total of 420m in front of some commercial properties off Crew’s Hole Road on the North bank of the River Avon. For this reach, a precautionary approach to construct defences in the 2020s to the 2125 SoP has been assumed for the costing due to anticipated buildability complexities. These defences need to mitigate flood risk as well as detriment, therefore the highest of FCERM 2125 with freeboard and NPPF 2125 without freeboard has been assumed in the costing.

This defence ties into the detriment mitigation measures upstream of Crew’s Hole Road, refer to section 4.1.4 for more details.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- Construction in the riverbank may have significant Health and Safety and environmental impact as well as interfering with the natural beauty of the area, closure of the river path and limiting public use for activities such as fishing.

Opportunities

- Further topographic survey information may reduce the extent of the works.

3.5 Reach 16 – St Anne’s (South Bank)

Further modelling has shown that new defences are required upstream of Netham Weir on the South Bank, for a total of 1120m on the North bank of the River Avon. This reach is like the detriment mitigation measures previously proposed by AECOM, although extends 70m further downstream.

For this reach, a precautionary approach to construct defences in the 2020s to the 2125 SoP has been assumed for the costing due to anticipated buildability complexities, except for the 110m from the downstream end which is only required in 2065. These defences need to mitigate flood risk as well as detriment, therefore the highest of FCERM 2125 with freeboard and NPPF 2125 without freeboard has been assumed in the costing.

This defence ties into the detriment mitigation measures around Brislington Brook, refer to 4.1.4 for more details.

Risks

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- Construction in the riverbank may have significant Health and Safety and environmental impact as well as interfering with the natural beauty of the area, closure of the river path and limiting public use for activities such as fishing.
- There is an existing jetty which may be a historical/heritage structure. There is a risk that the proposed flood defence may not be buildable if the jetty cannot be decommissioned.
- Construction details of the existing defences are unknown.

Opportunities

- No major opportunities have been identified.

4 Detriment mitigation measures

4.1 City Centre Detriment Mitigation

City Centre Detriment Mitigation measures include defences or upgrades to existing defences required on the River Avon. The flood defence level assumed in costing of the detriment mitigation measures is the highest of either the NPPF SoP without freeboard or FCERM SoP with freeboard. This approach is further explained in the Arup Detriment Mitigation Report [3].

Avon defences

Left Bank of Avon near the Malago

A 100m-long defence is required on the left bank of the Avon, parallel to Coronation Road, after 2065. The existing wall needs to be raised by an average height of 0.5m relative to existing ground levels.

Left Bank of Avon new St. Philip's Causeway

A 106m-long defence is required on the left bank of the Avon, parallel to Whitby Road upstream of St Philip's Causeway, after 2065. An embankment of an average height of 0.4m has been assumed for costing which is to be further detailed at the next stage.

4.1.1 Chapel Way Defence

Defences around Chapel way are required to reduce Brislington Brook overland flow as discussed in the Arup Detriment Mitigation Report [3].

AECOM proposed a range of measures on the Brislington Brook. These included raising of existing sheet piled; installing a tidal flap valve at the Brislington Brook outfall; culverting the open section of Brislington Brook or raising the defences around it and providing overpumping when Brislington Brook cannot discharge under gravity.

An earth embankment up to 3.5m high, built up against the existing wall, will be constructed in the 2020s. The embankment will have a 1:3 slope and a crest width of 2m.

The Chapel Way defence effectively provides flood storage in St Anne's Wood. The flood storage embankment at Chapel Way is significant. The defence should be designed to allow overtopping in exceedance events. The stored flood volume above ground level is greater than 25,000m³ and would be classified as a large raised reservoir under the Reservoir Act and would need to be registered with the EA and have a panel engineer appointed. Given the reservoir is in an urban area with properties and rail infrastructure downstream, the reservoir is likely to be considered as being high risk requiring appointment of a supervising engineer and an inspecting engineer.

4.1.2 Brislington Boat Screen

As discussed in the Arup Detriment Mitigation Report [3], enlargement of the Brislington Boat Screen culvert inlet is likely to be required in the 2020s. It is proposed that further investigation of the screen is carried out to inform the extent of the works required.

4.1.3 Malago defences

AECOM proposed seven additional properties at risk should have property level protection (PLP) installed as construction of a new hard defence against flooding was not considered to be viable. Although it was noted the properties which are already at flood risk will suffer a maximum increase of only 60mm, in some cases the total flood depth exceeds 600mm the depth at which PLP is not considered effective or desirable due to the potential for structural damage. Further modelling has now demonstrated a viable approach to containing the slight change of water levels within the river corridor. The Malago outfall has an existing flap valve in operation.

Malago Left Bank

As discussed in the Arup Detriment Mitigation Report [3], 120m of the Malago left bank upstream of Parson Street requires raising in 2065. The extent of raising is to be developed in future studies, we have assumed that 0.75m of wall raising will be required.

Malago Flood Storage

As discussed in the Arup Detriment Mitigation Report [3], 'Marksbury Open Space' is proposed as flood storage on the Malago. These details will be developed in future studies.

4.1.4 St. Anne's defences

St. Anne's North bank, Crew's Hole Road

The defences at St. Anne's North Bank (reach 15) need to be extended beyond Crew's Hole Road as detriment mitigation measures. For this 994m extension, a floodwall will be constructed in the 2020s to the NPPF 2125 SoP without freeboard.

Due to a lack of topography survey and private properties threshold level information, we have taken a precautionary approach and provided a floodwall for the entire length. The height and extent of the defences could be reduced after carrying out further surveys as well as public engagement.

St. Anne's South bank, Brislington Brook

The defences at St. Anne's South Bank (reach 16) need to account for detriment mitigation measures around Brislington Brook. For this 140m extension, a

floodwall will be constructed in the 2020s to the FCERM 2065 SoP and then raised in 2065 to the NPPF 2125 SoP without freeboard.

4.1.5 Risks and Opportunities

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- The defences costed for Chapel Way are significant embankments with a high visual impact and can also have significant buildability issues but as the design is developed a more sympathetic embankment approach can be developed.
- Construction details of existing defences are unknown.
- Insufficient Lidar and environmental information around these detriment mitigation measures may lead to flood defence requirements changing as the design develops. This may vary the costs in future stages.
- As noted in section 4.1.4, around Crew's Hole Road, the extent of the defences could be reduced after carrying out further surveys including threshold survey of the surrounding properties as well as public engagement.
- Further topographic surveys may reduce the extent of the works.
- The detriment mitigation approach assumes that there are no connections from the existing surface water drainage network to the Brislington Brook culvert. Surveys and further design are required, with installation of non-return valves or diversions.

4.2 Downstream Detriment Mitigation

4.2.1 Shirehampton defences

850m of detriment mitigation defences are required at Shirehampton.

For the sections east and west of Station Road, we have adopted an adaptive approach of:

- a) raising the existing embankments to the FCERM 2065 SoP in the 2020s
- b) raising the embankments again in 2065 to the FCERM 2125 SoP with freeboard.

The Environment Agency own, operate and maintain the raised tidal defences at Shirehampton. Recent works have including replacing the tidal flood gate and infilling a redundant gate. No works are currently planned. The defences are located adjacent to the Lamplighters area of the Shirehampton Conservation Area.

4.2.2 Pill defences

1075m of detriment mitigation defences are required at Pill. An adaptive approach of providing defences to the FCERM 2065 SoP in the 2020s and raising the defences again in 2065 to the FCERM 2125 SoP with freeboard is assumed in the costing.

The Environment Agency own, operate and maintain the raised tidal defences at Pill. Recent works include embankment maintenance and repairs to the tidal flood gates. An investigation into the condition of the sheet pile wall is ongoing and repairs may be necessary. A wider study is ongoing works to sustain or improve the Standard of Protection within the Pill area including the Markham Brook watercourse and associated pumping station, culvert and screen.

4.2.3 Sea Mills defences

740m of detriment mitigation defences are proposed at Sea Mills. An adaptive approach of providing defences to the FCERM 2065 SoP in the 2020s and raising the defences again in 2065 to the FCERM 2125 SoP with freeboard is assumed in the costing.

There are no formal raised flood defences in the area. One property flooded internally in the March 2020 high tides. The Council is planning a study to improve hydraulic modelling in the area and investigate options to better protect properties along the reach now and in the future.

4.2.4 Risks and Opportunities

The following project risks have been identified through this study and are assessed in the Live Project Risk Register:

- At Shirehampton, the embankment proposed may restrict access for the Sea Cadets to the River. If the embankment is aligned behind the Sea Cadets to allow access their property will be flooded. Amendments to the flood gate may be required to maintain access to the river for the Sea Cadets. Consultation with the Sea Cadets to understand their requirements should be undertaken at the next stage.
- Land ownership at Pill around Watchhouse Road is currently not well understood.
- At Sea Mills, the railway bridge across the River Trym may get inundated due to rising water levels. More defence works may be required to tie in the proposed embankments to the railway abutments to prevent flooding of properties from flooding of the railway.
- Construction works may have negative environmental and health & safety impacts.
- Construction details of existing defences are unknown.
- There are opportunities to align with any subsequent flood risk management works by the Environment Agency or Bristol City Council at Pill and Sea Mills.

4.3 Upstream defences

We have identified possible detriment mitigation measures upstream of the A4174 main road as far as Swineford. The Arup Detriment Mitigation Report [3] and the Upstream detriment mitigation scoping note [14] states that these falls outside of the 2D model domain. It was agreed that the development and testing of these measures should be undertaken in future stages of the project, potentially at the Outline Business Case stage following further hydraulic modelling.

Based on the 1D model domain the detriment measures upstream of A4174 have been combined as embankments that are:

- a) built in 2020s to an average height of 1m
- b) raised in 2065 to an additional average height of 0.5m for costing purposes only.

Following the Winter 2013 floods, the Environment Agency undertook engagement with the communities of Hanham, properties at Willsbridge, Broadmead Ind Estate, Bitton and Swineford. A high-level options appraisal in 2014/15 concluded defences were not straight-forward or cost effective; which led to delivery of PFR measures through the 2015/16 programme. Engagement highlighted the community perception that the operation of Twerton Gates negatively affects the area.

5 Summary and Conclusions

Further modelling work by Arup has meant that the re-alignment of the defences and elevated flood levels has increased design flood defence levels.

This report outlines the updates to the previously proposed defences by AECOM and inputs into an economic assessment. This will determine, with BCC, the best options for the Bristol Flood Strategy scheme.

The preferred option for the scheme on economic grounds is set out in the SOC, based on analysis of multiple options for the defences. For this report, an adaptive approach to the defences has been assumed:

- a) an initial construction phase in the 2020s to the FCERM 2065 SoP
- b) further work in 2065 to meet the FCERM 2125 SoP.

The exception to this approach is at Entrance Lock / Western Harbour and at Bristol Temple Quarter / St. Philips Marsh, areas identified for potential growth and regeneration. At Entrance Lock, the NPPF standard of protection is assumed in costing. At Bristol Temple Quarter / St. Philips Marsh, the FCERM SoP has been assumed for the costing of the defences for the 2020s. It is assumed that the new developments at BTQ will provide flood defences to NPPF 2125 levels. A precautionary approach to build defences to relevant 2125 SoPs has also been adopted at specific locations due to the complexity of phasing the works.

The costing considers two different levels of public realm enhancements; low and high. Placemaking opportunities such as terracing to floodwalls at the Entrance Lock and raising the floodwalls with flood glass parapets have been considered to reduce the visual impact of any new structure.

A summary of the main differences to the AECOM defences as a result of the updated fluvial/tidal modelling work are presented in Table 1.

Table 1: Magnitude of changes to scope of works as a result of additional fluvial/tidal modelling

Area description	Magnitude of Change
Reaches 1 to 8 (low and high defences), approx. 5km length, AECOM Proposed defences 0.5 to 1.5m height	Most of the original AECOM defences (low and high) will now be part of the phase 1 works. The average defence level for 2065 increased to 1.0m and to 2.0m in 2125 excluding dams, lock gates and river floodgates.
Reaches 10, 13, 14, 15, 16, approx. 5km length, 0.5 to 1.5m height	These are all new defences.
Downstream, city centre and upstream detriment measures, 7km length, 0.2 to 3.5m height	These are all new defences.

Risks to the design of the defences, and therefore costs, are set out in the individual sections regarding each reach. In summary these can be broadly grouped as:

- a) insufficient topographical information and geotechnical and structural investigations
- b) access for construction and stability of the riverbank
- c) heritage and environmental risks
- d) land ownership risks
- e) stakeholder engagement: consultation is recommended and may significantly influence the defences and therefore costs
- f) insufficient UXO and utilities information
- g) limited access and space for site compounds necessitating road closures or temporary disturbance to public open spaces
- h) interface with strategic drainage outfall assets.

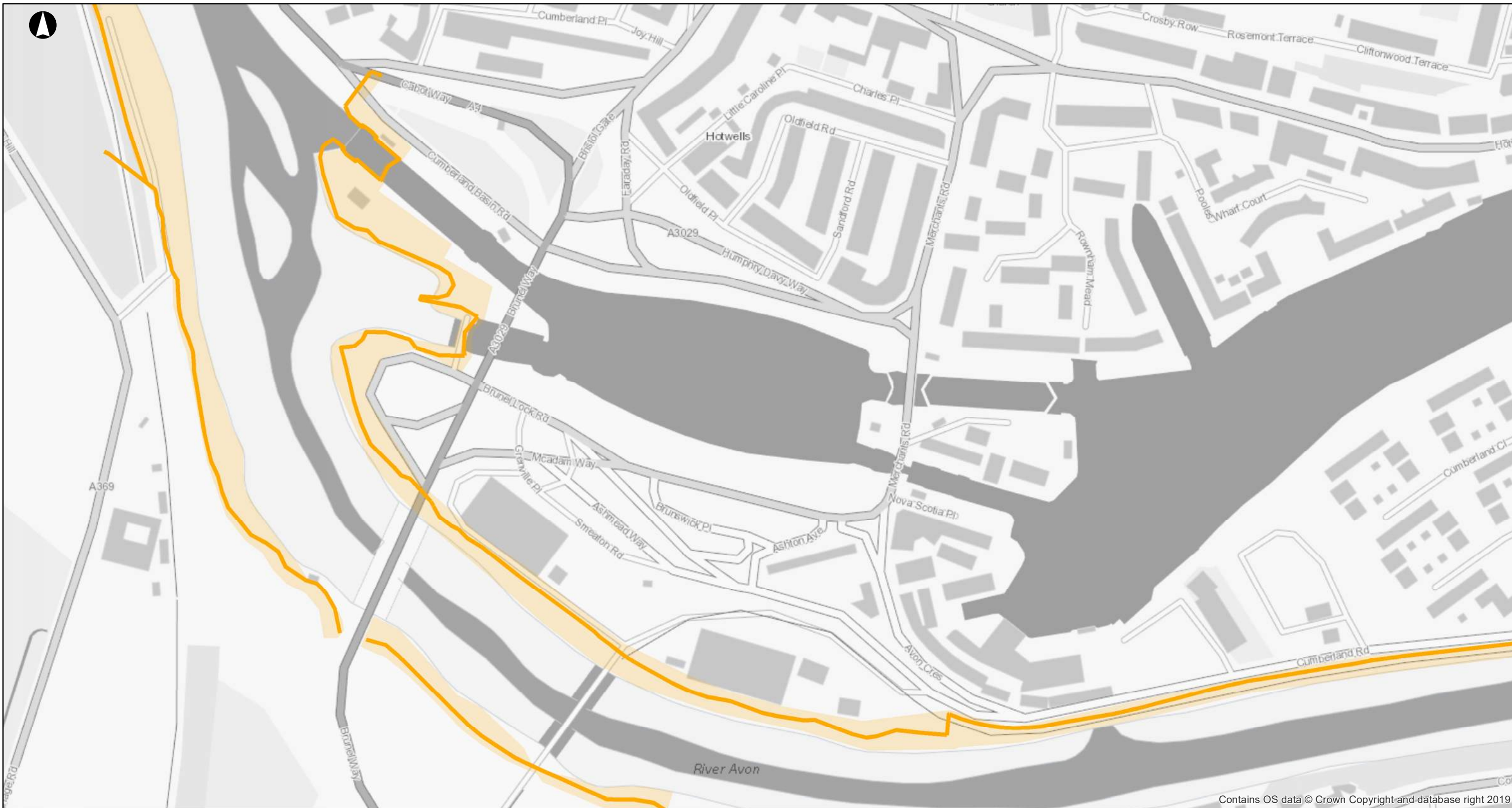
The current delivery risk register is appended.

The bridges along the River Avon and Floating Harbour area are at risk of getting inundated as a result of rising flood levels. Mitigation measures for these risks have not been considered as part of this strategy as this risk is not a result of the works proposed by this strategy.

There are opportunities for the scheme to consider using existing structures with further investigations.

The magnitude of the detriment mitigation measures can potentially be adjusted by considering the local topography once detailed surveys are completed as well as considering the local flood risk.

Appendix A – Defence alignments



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Legend

Potential extent of defences subject to consultation and detailed design

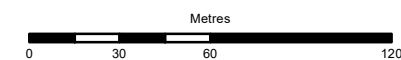
- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

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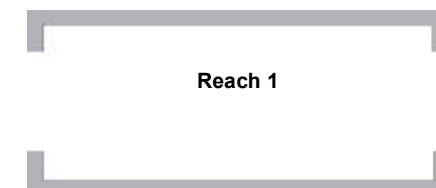
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Legend

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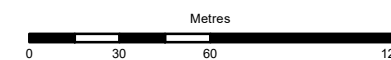
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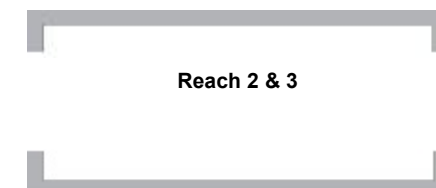
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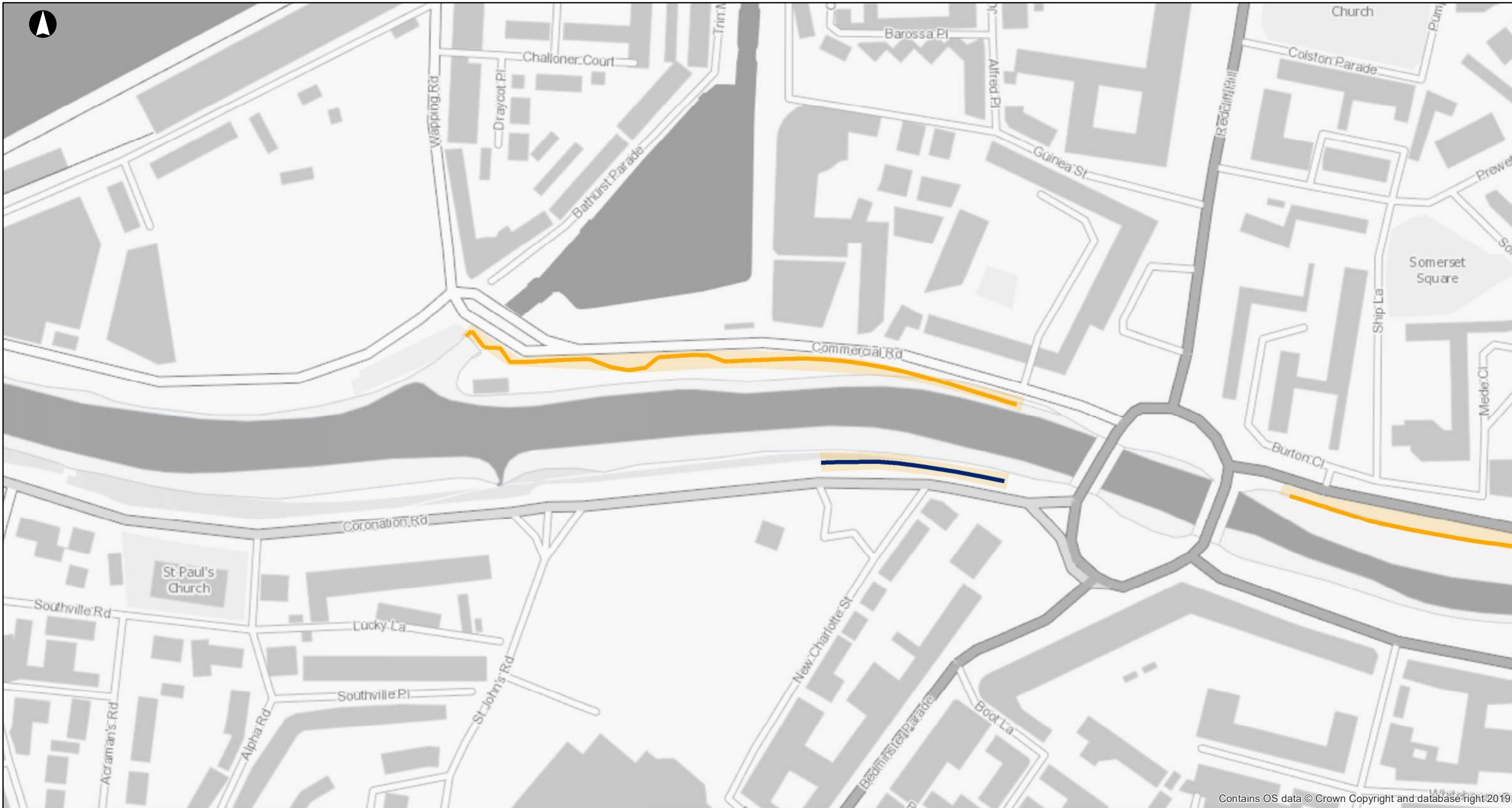
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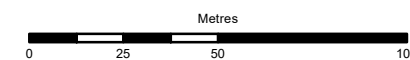
Potential extent of defences subject to consultation and detailed design

- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

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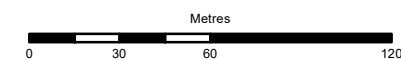
- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

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Potential extent of defences subject to consultation and detailed design

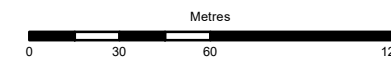
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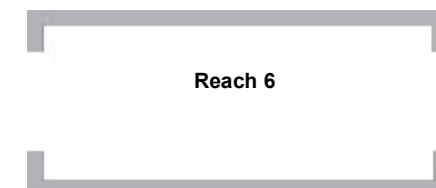
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Legend

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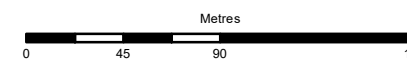
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- Potential extent of defences subject to consultation and detailed design

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Reach 7 & 13

Scale at A3

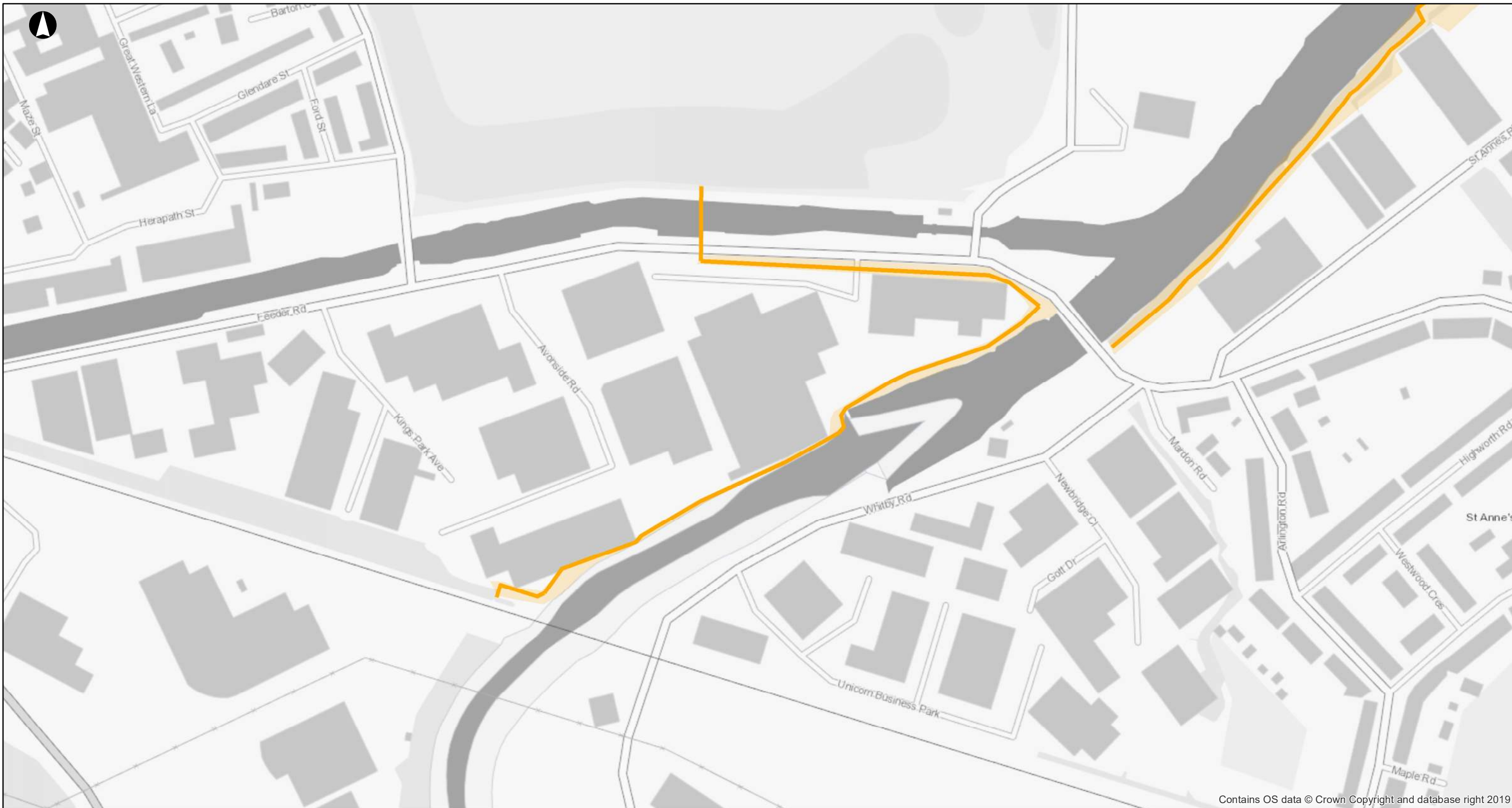
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Job No
260498

Drawing Status
FOR INFORMATION

Drawing No
393

Issue
P1



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Legend

Potential extent of defences subject to consultation and detailed design

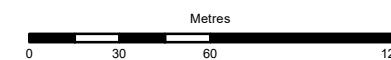
- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

P1	2020-08-06	HW	PS	HR
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Issue	Date	By	Chkd	Appd
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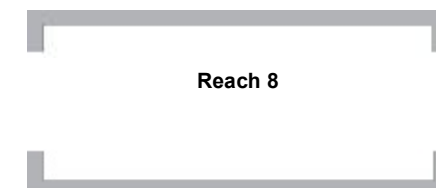
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www.arup.com



Client
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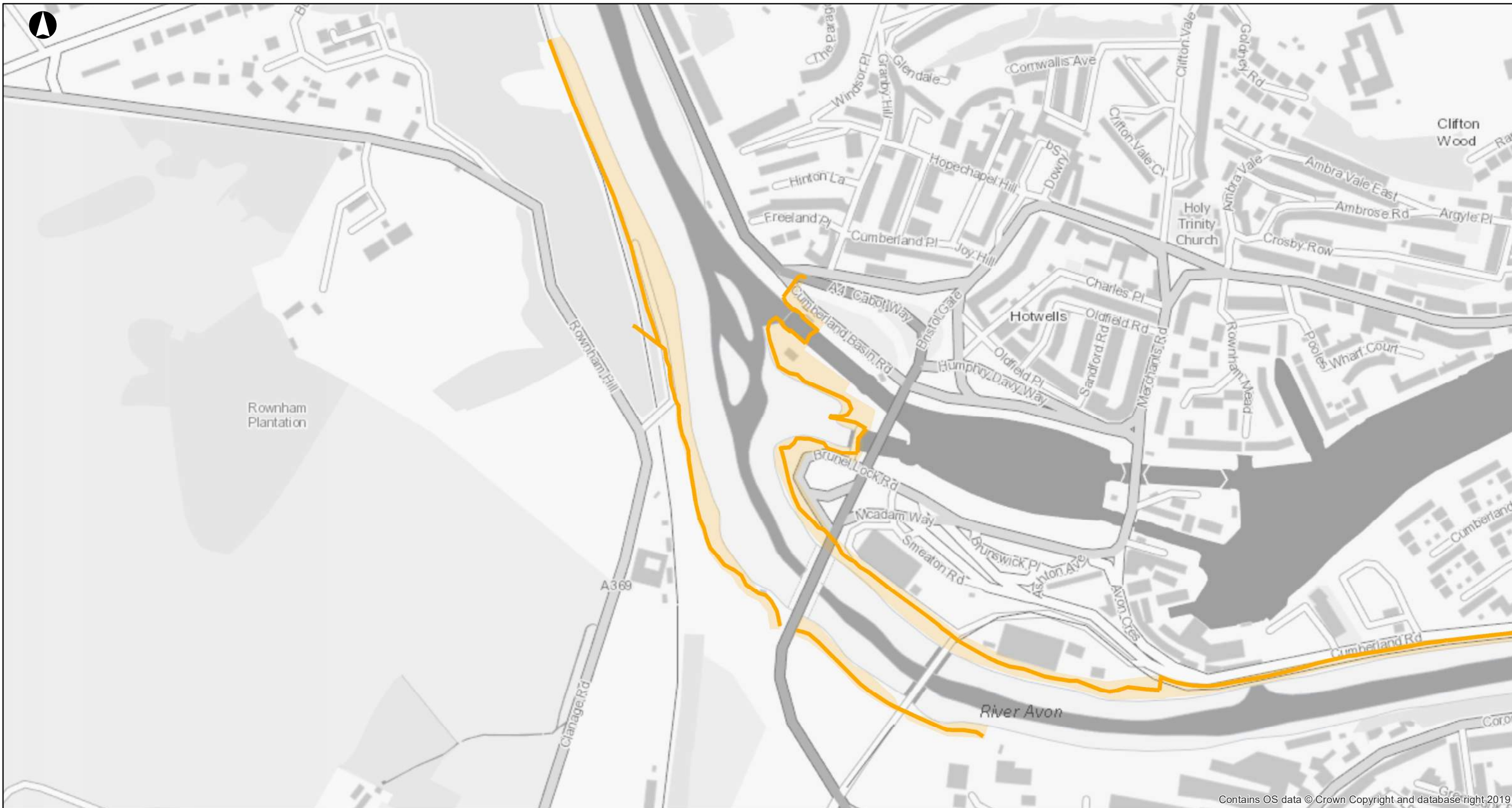
Job Title
BRISTOL FLOOD STRATEGY



Scale at A3
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Job No 260498	Drawing Status FOR INFORMATION
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Drawing No 381	Issue P1
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Legend

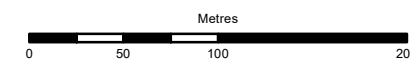
Potential extent of defences subject to consultation and detailed design

- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

P1	2020-08-06	HW	PS	HR
Issue	Date	By	Chkd	Appd

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Job Title

BRISTOL FLOOD STRATEGY

Reach 10

Scale at A3

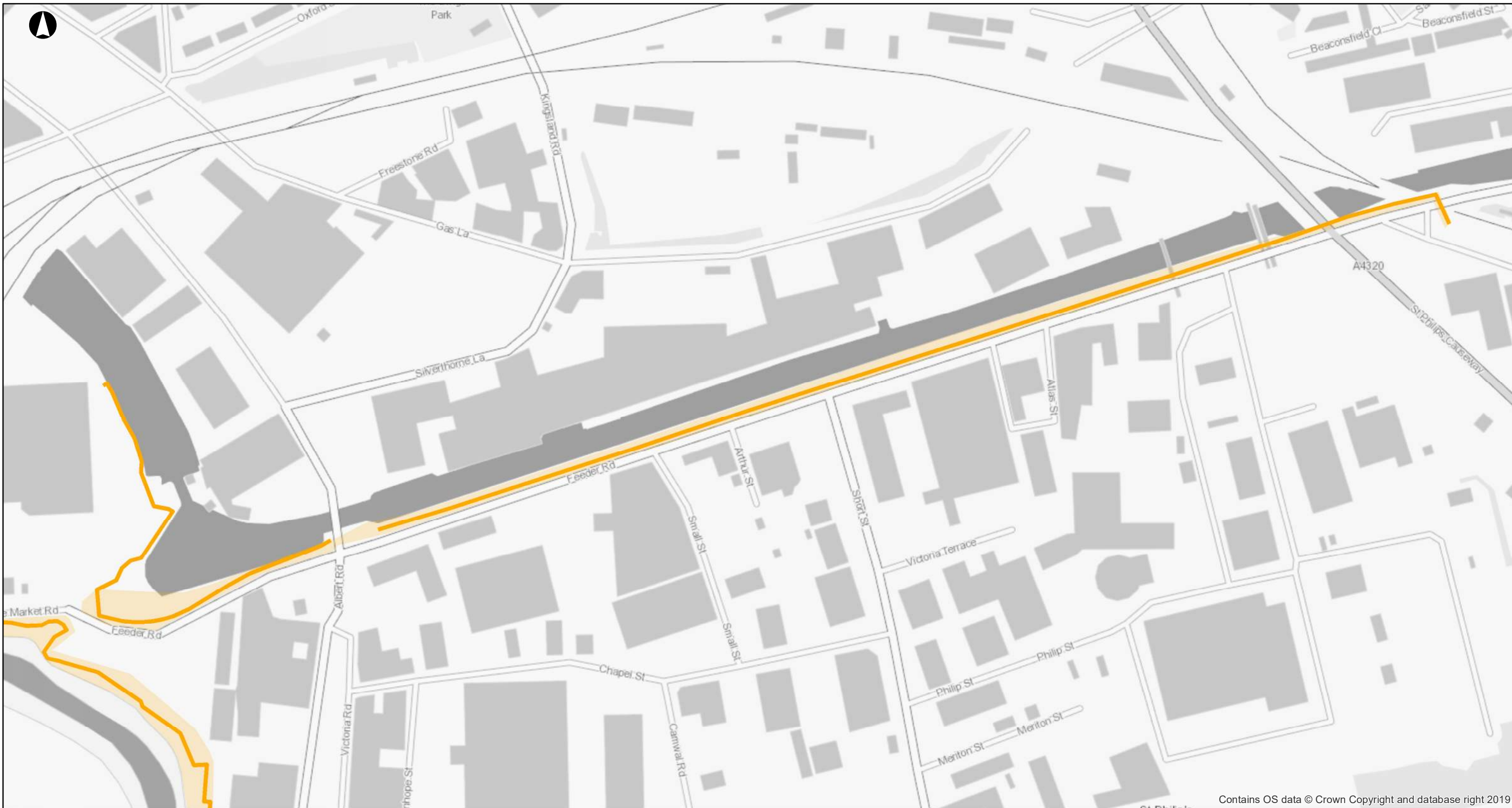
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Job No
260498

Drawing Status
FOR INFORMATION

Drawing No
382

Issue
P1



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Legend

Potential extent of defences subject to consultation and detailed design

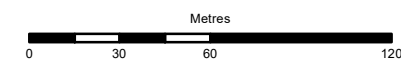
- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

P1	2020-08-06	HW	PS	HR
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Issue	Date	By	Chkd	Appd
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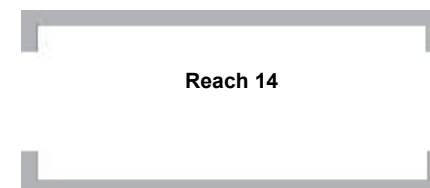
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Scale at A3
1:2,500

Job No 260498	Drawing Status FOR INFORMATION
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Drawing No 383	Issue P1
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Legend

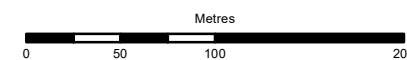
Potential extent of defences subject to consultation and detailed design

- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

P1	2020-08-06	HW	PS	HR
Issue	Date	By	Chkd	Appd

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Job Title

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Reach 15 & 16

Scale at A3

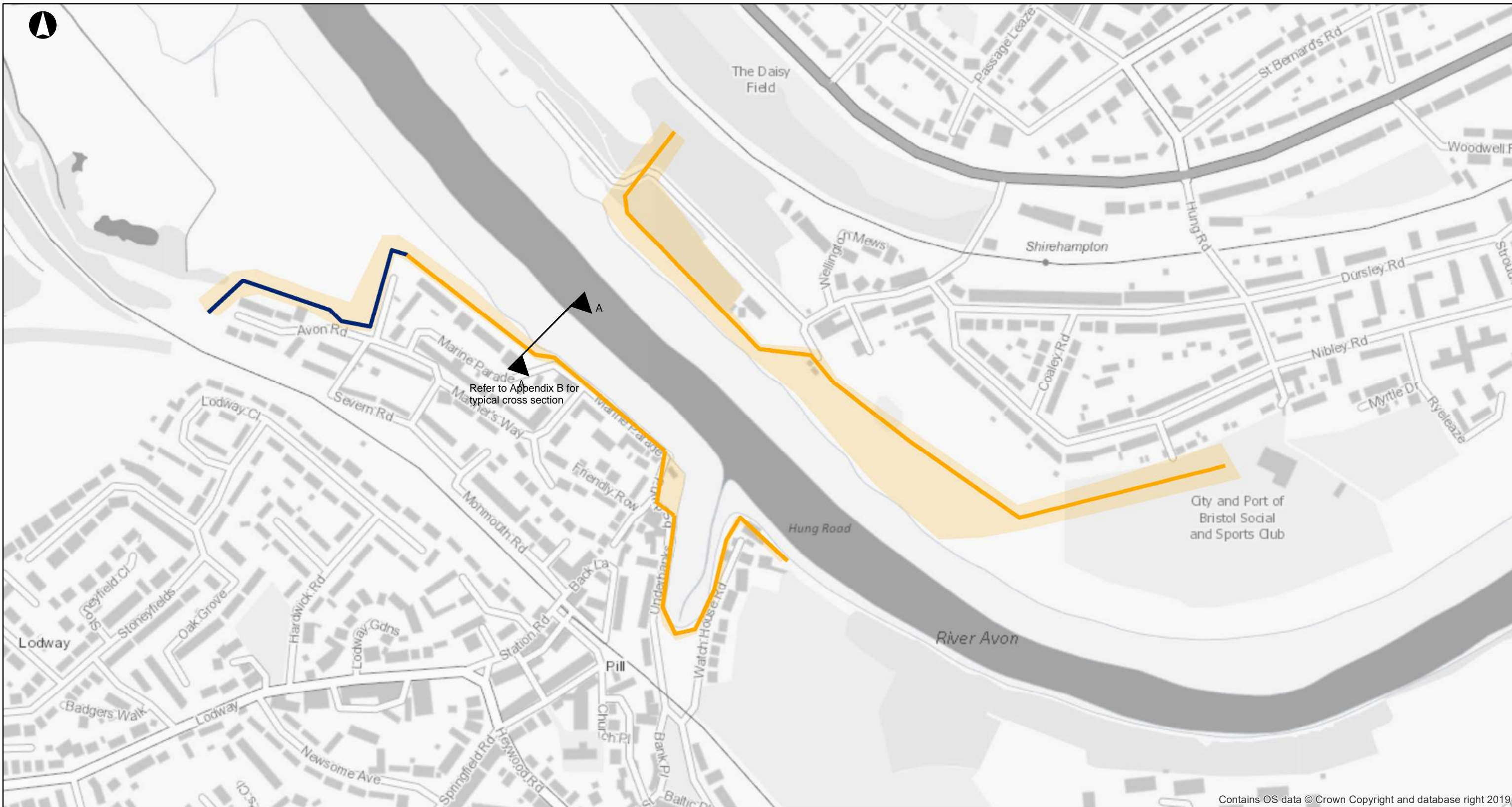
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Job No
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Drawing Status
FOR INFORMATION

Drawing No
384

Issue
P1



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Legend

Potential extent of defences subject to consultation and detailed design

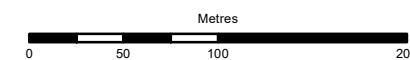
- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

P1	2020-08-06	HW	PS	HR
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Issue	Date	By	Chkd	Appd

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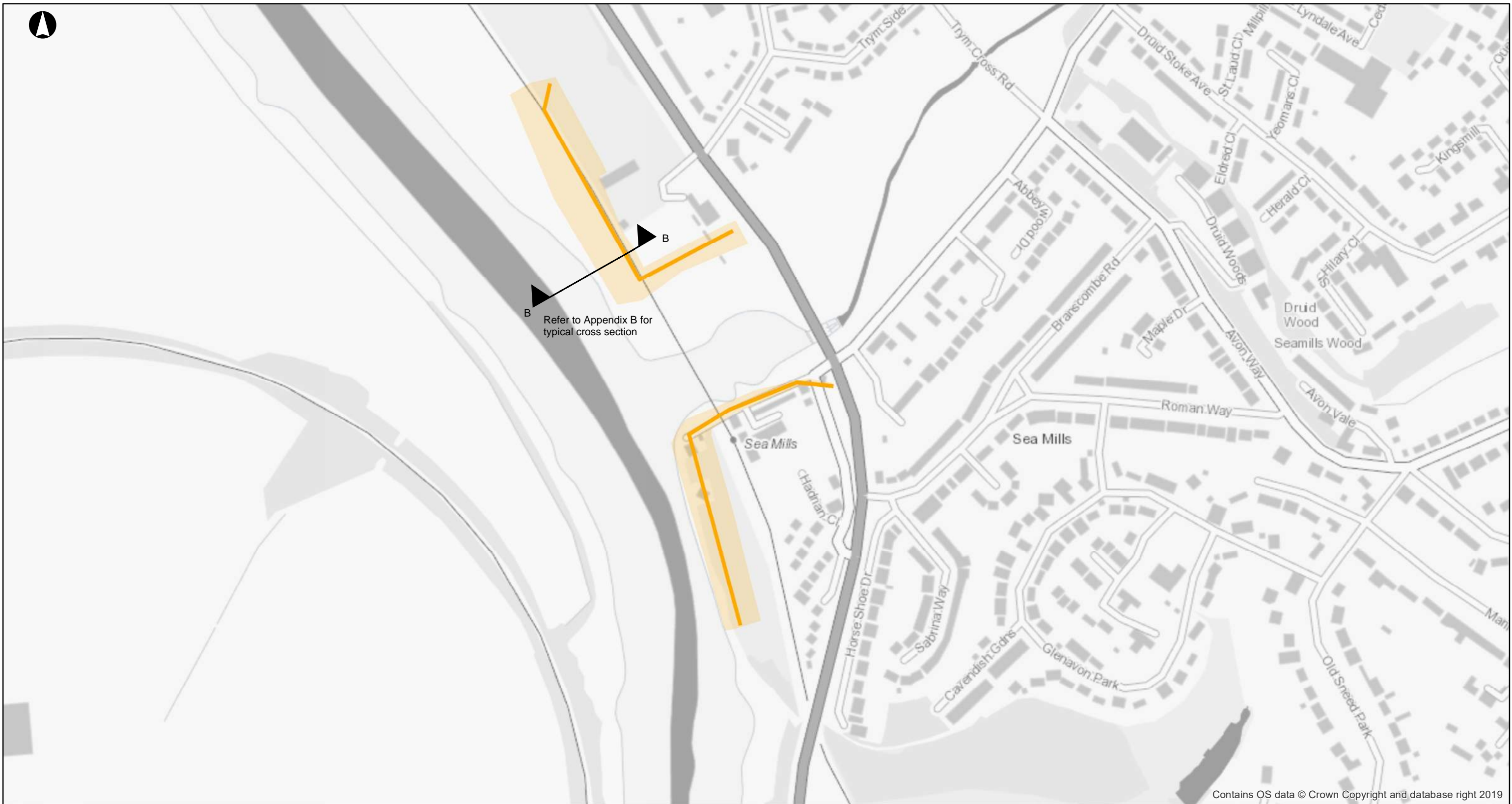
Job Title
BRISTOL FLOOD STRATEGY



Scale at A3

1:4,000

Job No 260498	Drawing Status FOR INFORMATION
Drawing No 385	Issue P1



Refer to Appendix B for typical cross section

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Legend

Potential extent of defences subject to consultation and detailed design

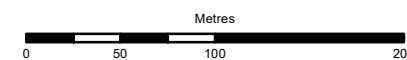
- Proposed alignment of defences to be constructed in 2020s
- Proposed alignment of defences to be constructed in 2060s
- Potential extent of defences subject to consultation and detailed design

P1	2020-08-06	HW	PS	HR
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Issue	Date	By	Chkd	Appd
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Job Title

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Scale at A3

1:4,000

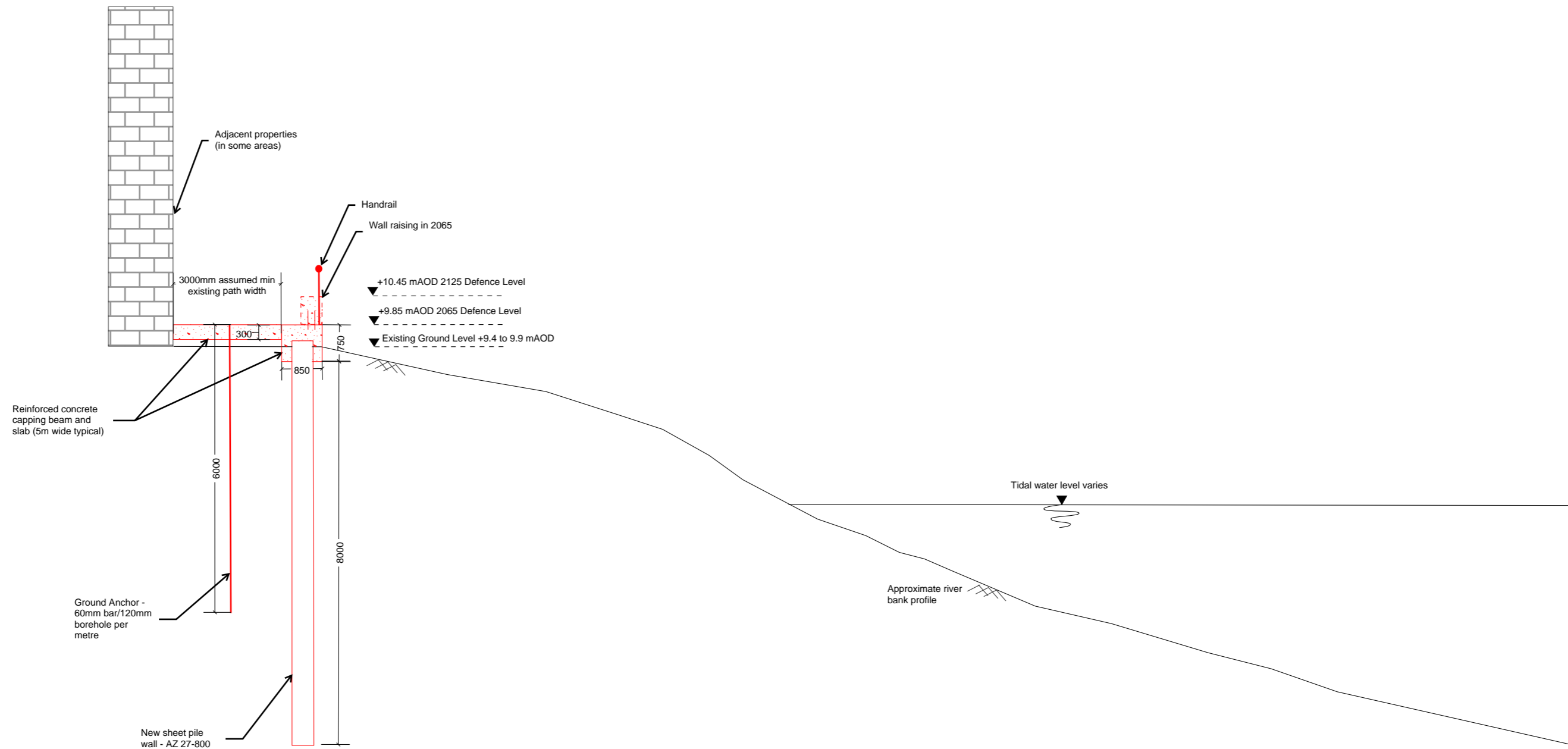
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Drawing Status
FOR INFORMATION

Drawing No
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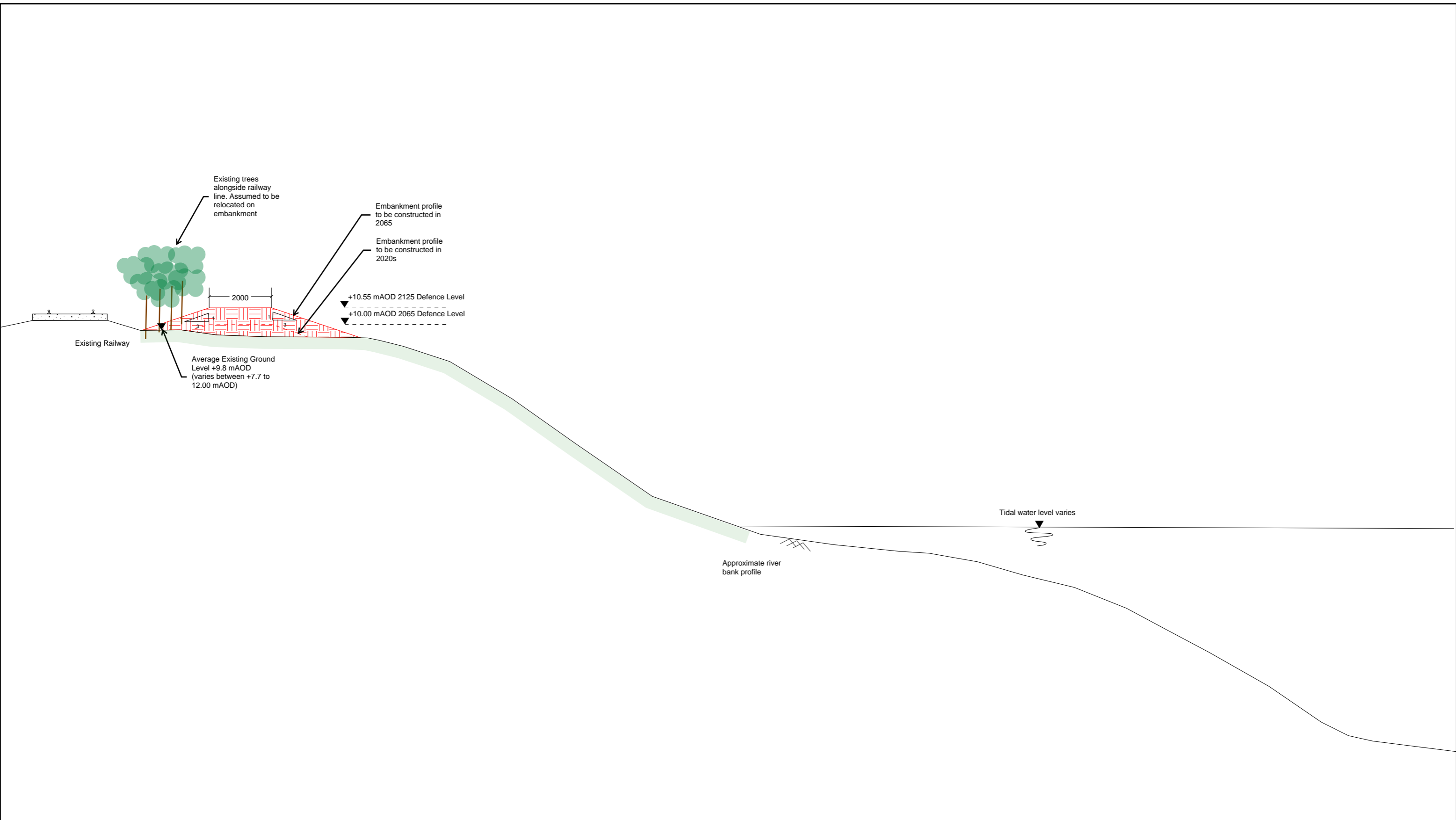
Issue
P1

Appendix B – Detriment Mitigation Defences Cross-section



DETRIMENT MITIGATION AT PILL - TYPICAL NEW SHEET PILED FLOOD WALL SECTION A-A

ARUP			
Job Title		Job No.	
Bristol Flood Strategy		260498-00	
Sketch Title		Sketch No.	
Pill DM - Sheet piled wall		SK-017	
Purpose of Issue		Scale	
For Information		NTS	
By	Checked	Revision	Date
RJ	RJ	01	17/08/20



DETRIMENT MITIGATION AT SEA MILLS - TYPICAL
NEW EARTH EMBANKMENT SECTION B-B

ARUP			
Job Title		Job No.	
Bristol Flood Strategy		260498-00	
Sketch Title		Sketch No.	
Sea Mill DM - Embankment		SK-018	
Purpose of Issue		Scale	
For Information		NTS	
By	Checked	Revision	Date
RJ	RJ	01	17/08/20

Appendix C - Defence heights

Key:

Low defence	<0.85m
Medium defence	<1.1m
High defence requiring mitigation	<1.5m
Defence requiring extensive mitigation	>1.5m
N/A	
Dock gate/dam	

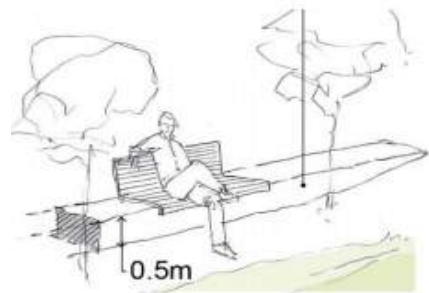
Notes:

0.85m - In the absence of specific guidance, to maintain sightlines from a seated position then the parapet height should not exceed 0.85m above pavement level (Approved Document M Volume 1, which refers to interiors for windows without obstruction for wheelchair users – but the same principle can be inferred to providing accessible views).

1.1m maximum parapet height above pavement level could be relaxed whilst still allowing wheelchair users views above the horizon line. 1.1m would maintain horizon line above wall from seated position - considered to be eye-level for a wheelchair user (i.e. 1.2m (485mm wheelchair seat + 740mm average eye level seated woman above seat level [https://www.firstinarchitecture.co.uk/average-heights-dimensions-of-person-sitting])). Aligns with requirement for provision of handrailing.



Medium Defences
Up to 1.1 metres
(A typical railing height)



Low Defences
Up to 0.5 metres
(A typical seat or bench)

<https://www.floodandcoast.com/assets/Uploads/Will-McBain-Arup-Sheffield-flood-protection-programme.pdf>

Average Defence Heights per Reach

		75 year SoP			100 year SoP			200 year SoP		
Reach		Average of Arup FCERM 2065 defence height (m)	Average of Arup FCERM 2125 defence height (m)	Average of Arup NPPF 2125 defence height (m)	Average of Arup FCERM 2065 defence height (m)	Average of Arup FCERM 2125 defence height (m)	Average of Arup NPPF 2125 defence height (m)	Average of Arup FCERM 2065 defence height (m)	Average of Arup FCERM 2125 defence height (m)	Average of Arup NPPF 2125 defence height (m)
		1		1.43	2.03	2.33	1.48	2.08	2.38	1.63
2		0.99	1.54	1.89	1.04	1.59	1.94	1.24	1.79	2.09
3		1.25	1.80	2.10	1.30	1.85	2.15	1.50	2.05	2.40
4		1.09	1.64	1.94	1.14	1.69	1.99	1.39	1.94	2.24
5		0.67	1.22	1.47	0.72	1.27	1.52	1.07	1.52	1.82
6		0.77	1.27	1.52	0.82	1.32	1.57	1.17	1.67	1.97
7		0.78	1.28	1.63	0.78	1.33	1.68	1.18	1.68	1.98
8		1.36	1.81	2.11	1.41	1.91	2.21	1.66	2.06	2.51
10		0.57	1.17	1.47	0.62	1.22	1.52	0.77	1.37	1.67
13		0.77	1.32	1.62	0.82	1.37	1.67	1.22	1.72	2.02
14		0.47	0.67	0.87	0.57	0.77	1.02	0.87	1.17	1.37
15		0.88	1.28	1.63	1.03	1.38	1.73	1.33	1.73	2.08
16		1.00	1.40	1.75	1.15	1.50	1.85	1.45	1.85	2.20
DM	City Centre Detriment	1.01	1.29	1.13	1.02	1.31	1.20	1.05	1.36	1.28
	Downstream Detriment	0.48	1.07	1.39	0.53	1.13	1.44	0.67	1.25	1.55
	Upstream of A4174 Detriment	1.00	1.50	1.50	1.00	1.50	1.50	1.00	1.50	1.50

Defence heights for the 75 year SoP

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)
1	Entrance Lock / Western Harbour		1 Floodwall					0.27	0.11	0.41
			2 Road Raising and floodgate		1.59	0.57	0.27	2.19	1.17	1.47
			3 Floodwall	1.59	4.48	2.84	2.19	5.08	3.44	3.74
			4 Ramp / floodgate /steps	3.70	4.82	4.47	4.30	5.42	5.07	5.37
			5 Lock gate	4.67	4.92	4.84	5.27	5.52	5.44	5.74
			6 Property Level Protection	9.85	9.85	9.85	10.45	10.45	10.45	10.75
			7 Property Level Protection	9.85	9.85	9.85	10.45	10.45	10.45	10.75
			8 Floodwall	1.58	5.94	2.72	2.18	6.54	3.32	3.62
			9 Upgrade and raising of existing structure	3.67	4.47	3.88	4.27	5.07	4.48	4.78
			10 Ramp	0.91	1.03	0.95	1.51	1.63	1.55	1.85
			11 Floodwall	0.78	1.63	1.26	1.38	2.23	1.86	2.16
			12 Floodwall	0.90	4.53	1.96	1.50	5.13	2.56	2.86
			13 Floodwall	0.65	1.35	0.93	1.25	1.95	1.53	1.83
			14 Use existing structure	9.85	9.85	9.85	10.45	10.45	10.45	10.75
			15 Ramp	0.82	1.31	1.05	1.42	1.91	1.65	1.95
			16 Floodwall	0.40	1.35	1.12	1.00	1.95	1.72	2.02
			17 Ramp	0.27	0.62	0.41	0.87	1.22	1.01	1.31
			18 Floodwall	0.61	1.97	1.30	1.21	2.57	1.90	2.20
			19 Ramp	0.94	1.97	1.44	1.54	2.57	2.04	2.34
			20 Floodgate	1.44	1.44	1.44	2.04	2.04	2.04	2.34
			21 Floodwall	0.86	1.68	1.45	1.46	2.28	2.05	2.35
			22 Underfall Yard Sluice	9.85	9.85	9.85	10.45	10.45	10.45	10.75
2	Cumberland Road		0 Existing Outfall	9.85	9.85	9.85	10.40	10.40	10.40	10.75
			1 Floodwall	0.95	1.39	1.11	1.50	1.94	1.66	2.01
			2 Floodwall	1.12	1.21	1.17	1.67	1.76	1.72	2.07
			3 Floodwall	0.68	1.11	0.94	1.23	1.66	1.49	1.84
			4 Floodwall		1.22	0.56	0.06	1.77	1.11	1.46
			5 Raise Defence	0.75	1.21	1.00	1.30	1.76	1.55	1.90
			6 Floodwall	0.88	1.38	1.15	1.43	1.93	1.70	2.05
3	Cumberland Rd East Defence		1 Floodgate	1.00	1.52	1.25	1.55	2.07	1.80	2.10
			Floodwall	1.00	1.52	1.25	1.55	2.07	1.80	2.10
			2 Ramp	1.00	1.52	1.25	1.55	2.07	1.80	2.10
4	Commercial Road / Bathurst Dam		0 Floodwall	1.46	1.51	1.45	2.01	2.06	2.00	2.30
			1 Upgrade and raising of existing structure	9.85	9.85	9.85	10.40	10.40	10.40	10.70
			1a Existing Outfall	9.85	9.85	9.85	10.40	10.40	10.40	10.70
			2a Floodwall	1.13	0.40	0.87	1.68	0.95	1.42	1.72
			2 Floodwall	3.41		0.75	3.96	0.40	1.30	1.60
			3 Floodwall	1.29	1.05	1.16	1.84	1.60	1.71	2.01
			4 Ramp	0.88	1.07	0.97	1.43	1.62	1.52	1.82
5 Floodwall	0.78	1.89	1.23	1.33	2.44	1.78	2.08			
6 Floodwall	0.66	1.94	1.21	1.21	2.49	1.76	2.06			
5	Clarence Road		0 Floodwall		0.40			0.95	0.20	0.45
			1 Floodwall	0.39	2.25	1.24	0.94	2.80	1.79	2.04
			2 Footbridge abutment	9.85	9.85	9.85	10.40	10.40	10.40	10.65
			3 Floodwall		1.84	1.12	0.28	2.39	1.67	1.92
6	Cattle Market Road		1 Floodwall		2.09	0.94	0.24	2.59	1.44	1.69
			2 Floodwall		3.17	0.60		3.67	1.10	1.35
			3 Use existing structure	9.80	9.80	9.80	10.30	10.30	10.30	10.55

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)
7	St. Philips Marsh / Totterdown Defences		1 Ramp	0.55	1.26	0.97	1.05	1.76	1.47	1.82
			2 Floodwall	1.10	1.40	1.21	1.60	1.90	1.71	2.06
			3 Floodwall	1.28	2.18	1.59	1.78	2.68	2.09	2.44
			4 Floodwall	0.75	1.15	1.15	1.25	1.65	1.65	2.00
			5 Floodgate	1.85	2.08	2.01	2.35	2.58	2.51	2.86
			6 Floodwall	1.03	1.53	1.27	1.53	2.03	1.77	2.12
			7 Ramp / floodgate	0.95	1.22	1.02	1.45	1.72	1.52	1.87
			8 Floodwall	1.09	1.52	1.45	1.59	2.02	1.95	2.30
			9 Floodwall	1.32	1.47	1.42	1.82	1.97	1.92	2.27
			10 Floodwall	1.31	1.55	1.41	1.81	2.05	1.91	2.26
			11 Floodwall	0.87	1.57	1.41	1.37	2.07	1.91	2.26
			12 Floodwall	0.46	0.89	0.57	0.96	1.39	1.07	1.42
			13 Ramp	0.36	0.48	0.41	0.86	0.98	0.91	1.26
			14 Floodwall	0.32	0.37	0.35	0.82	0.87	0.85	1.20
			15 Floodwall	0.13	0.32	0.20	0.63	0.82	0.70	1.05
			16 Floodwall	0.26	0.34	0.31	0.76	0.84	0.81	1.16
			17 Floodwall	0.12	0.34	0.22	0.62	0.84	0.72	1.07
			18 Floodwall		0.73	0.33		1.23	0.83	1.18
			19 Existing bridge abutment	9.85	9.85	9.85	10.35	10.35	10.35	10.70
			20 Ramp		0.88	0.54		1.38	1.04	1.39
			21 Floodwall	0.51	0.65	0.57	1.01	1.15	1.07	1.42
			22 Floodwall	0.44	0.80	0.59	0.94	1.30	1.09	1.44
			23 Floodwall	0.68	0.83	0.77	1.18	1.33	1.27	1.62
			24 Floodwall	0.57	0.87	0.72	1.07	1.37	1.22	1.57
			25 Floodwall	0.58	0.84	0.67	1.08	1.34	1.17	1.52
			26 Floodwall	0.75	0.82	0.78	1.25	1.32	1.28	1.63
			27 Floodwall	0.53	1.59	1.13	1.03	2.09	1.63	1.98
			28 Floodwall	0.09	0.71	0.19	0.59	1.21	0.69	1.04
			29 Ramp	0.31	0.45	0.40	0.81	0.95	0.90	1.25
			30 Embankment	0.47	0.54	0.50	0.97	1.04	1.00	1.35
			31 Ramp	0.45	0.65	0.50	0.95	1.15	1.00	1.35
			32 Embankment	0.53	0.68	0.61	1.03	1.18	1.11	1.46
			33 Ramp	0.66	0.67	0.67	1.16	1.17	1.17	1.52
			34 Embankment	0.36	0.76	0.62	0.86	1.26	1.12	1.47
			35 Ramp	0.60	0.63	0.62	1.10	1.13	1.12	1.47
			36 Embankment		0.15	0.10	0.49	0.65	0.60	0.95
8	Netham Lock		1 Floodwall		1.79	0.81		2.24	1.26	1.56
			2a Floodwall	3.92	3.55	1.66	4.37	4.00	2.11	2.41
			2 Floodwall	3.92	3.55	1.66	4.37	4.00	2.11	2.41
			3 Floodwall		1.11	0.58	0.24	1.56	1.03	1.33
			4 Ramp		0.23	0.04	0.43	0.68	0.49	0.79
			5 [Removed from Scheme]	10.10	10.10	10.10	10.55	10.55	10.55	10.85
			6 Floodwall	1.00	3.23	2.71	1.45	3.68	3.16	3.46
			7 River Floodgate	6.12	7.04	6.58	6.57	7.49	7.03	7.33
			8 Floodwall		3.22	1.33	0.28	3.67	1.78	2.08
			9 [Removed from Scheme]	10.10	10.10	10.10	10.55	10.55	10.55	10.85
			10 Embankment		3.10	2.10		3.55	2.55	2.85
			11 Modifications to sluice structure at Netham Weir	10.10	10.10	10.10	10.55	10.55	10.55	10.85
12 Modifications to outfall from Avon side Road	10.10	10.10	10.10	10.55	10.55	10.55	10.85			

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)
10	Bower Ashton		1a Floodwall		1.79	0.51		2.39	1.11	1.41
			1b Embankment		1.79	0.51		2.39	1.11	1.41
			1c Existing Outfall	9.85	9.85	9.85	10.45	10.45	10.45	10.75
			2 Existing structure	9.85			10.45	10.45	10.45	10.75
			3 Embankment	0.51	1.44	0.90	1.11	2.04	1.50	1.80
			4 Floodgate	0.18	0.92	0.54	0.78	1.52	1.14	1.44
			4a Existing Outfall	9.85	9.85	9.85	10.45	10.45	10.45	10.75
			5 Embankment		1.60	0.38		2.20	0.98	1.28
			1 Existing road - no work	0.00	0.00	0.00	10.35	10.35	10.35	10.65
			2 Floodwall		1.77			2.32		
13	Totterdown South Defences		3 Raising existing structure	0.05	4.72	2.58	0.60	5.27	3.13	3.43
			1 Floodwall		1.55			1.75	0.19	0.39
			2 No work	8.35	8.35	8.35	8.55	8.55	8.55	8.75
			3 Floodwall	0.26	1.58	0.95	0.46	1.78	1.15	1.35
			1 Floodwall	0.82	1.24	1.04	1.22	1.64	1.44	1.79
			2 Floodgate	0.78	1.06	0.95	1.18	1.46	1.35	1.70
15	St. Anne's North Bank		3 Floodwall		3.99	1.45	0.14	4.39	1.85	2.20
			4 Floodgate		1.49	0.49		1.89	0.89	1.24
			5 Floodwall		1.49	0.49		1.89	0.89	1.24
			1 Floodwall	0.32	3.51	1.00	0.72	3.91	1.40	1.75
			2 Floodwall	0.32	3.51	1.00	0.72	3.91	1.40	1.75
DM	City Centre Detriment		10 Raise Defence		0.10	0.00	0.40	0.60	0.50	0.50
			11 Embankment	0.28	0.52	0.40	0.28	0.52	0.40	0.40
			12 Embankment	3.30	3.50	3.40	3.30	3.50	3.40	3.40
			13 Upgrade to existing structure	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			14 Embankment	0.00	0.00	0.00	0.00	0.00	0.75	0.00
			15 Upgrade to existing structure	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			16 Floodwall	0.55	3.74	1.23	0.70	3.89	1.38	1.36
DM	Downstream Detriment		1 Embankment	0.37	0.85	0.61	0.97	1.45	1.21	1.51
			2 Raise Defence	0.43	0.45	0.44	1.03	1.05	1.04	1.34
			3 Raise Defence	0.50	0.56	0.53	1.10	1.16	1.13	1.43
			4 Raise Defence	0.27	0.56	0.41	0.87	1.16	1.02	1.32
			5 Raise Defence		0.04		0.32	0.64	0.48	0.83
			5b Raise Defence		0.04		0.32	0.64	0.48	0.83
			6 Raise Defence	0.09	0.34	0.22	0.69	0.94	0.82	1.17
			6b Floodwall	0.09	0.34	0.22	0.69	0.94	0.82	1.17
			7 Embankment	1.46	2.04	1.75	2.06	2.64	2.35	2.70
			7b Floodwall	1.46	2.04	1.75	2.06	2.64	2.35	2.70
			8 Embankment		2.15	0.05		2.65	0.55	0.85
DM	Upstream of A4174 Detriment		9 Embankment		2.15	0.05		2.65	0.55	0.85
			17 Embankment	0.00	0.00	1.00	0.00	0.00	1.50	1.50

Defence heights for the 100 year SoP

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)	
1	Entrance Lock / Western Harbour	1	Floodwall				0.04	0.32	0.16	0.46	
			Road Raising and floodgate		1.64	0.62	0.32	2.24	1.22	1.52	
			3	Floodwall	1.64	4.53	2.89	2.24	5.13	3.49	3.79
				Ramp / floodgate /steps	3.75	4.87	4.52	4.35	5.47	5.12	5.42
			5	Lock gate	4.72	4.97	4.89	5.32	5.57	5.49	5.79
				Property Level Protection	9.90	9.90	9.90	10.50	10.50	10.50	10.80
			7	Property Level Protection	9.90	9.90	9.90	10.50	10.50	10.50	10.80
				Floodwall	1.63	5.99	2.77	2.23	6.59	3.37	3.67
			9	Upgrade and raising of existing structure	3.72	4.52	3.93	4.32	5.12	4.53	4.83
				Ramp	0.96	1.08	1.00	1.56	1.68	1.60	1.90
			11	Floodwall	0.83	1.68	1.31	1.43	2.28	1.91	2.21
				Floodwall	0.95	4.58	2.01	1.55	5.18	2.61	2.91
			13	Floodwall	0.70	1.40	0.98	1.30	2.00	1.58	1.88
				Use existing structure	9.90	9.90	9.90	10.50	10.50	10.50	10.80
			15	Ramp	0.87	1.36	1.10	1.47	1.96	1.70	2.00
				Floodwall	0.45	1.40	1.17	1.05	2.00	1.77	2.07
			17	Ramp	0.32	0.67	0.46	0.92	1.27	1.06	1.36
				Floodwall	0.66	2.02	1.35	1.26	2.62	1.95	2.25
			19	Ramp	0.99	2.02	1.49	1.59	2.62	2.09	2.39
				Floodgate	1.49	1.49	1.49	2.09	2.09	2.09	2.39
			21	Floodwall	0.91	1.73	1.50	1.51	2.33	2.10	2.40
				Underfall Yard Sluice	9.90	9.90	9.90	10.50	10.50	10.50	10.80
2	Cumberland Road	0	Existing Outfall	9.90	9.90	9.90	10.45	10.45	10.45	10.80	
			Floodwall	1.00	1.44	1.16	1.55	1.99	1.71	2.06	
			Floodwall	1.17	1.26	1.22	1.72	1.81	1.77	2.12	
			Floodwall	0.73	1.16	0.99	1.28	1.71	1.54	1.89	
			Floodwall		1.27	0.61	0.11	1.82	1.16	1.51	
			Raise Defence	0.80	1.26	1.05	1.35	1.81	1.60	1.95	
			Floodwall	0.93	1.43	1.20	1.48	1.98	1.75	2.10	
3	Cumberland Rd East Defence	1	Floodgate	1.05	1.57	1.30	1.60	2.12	1.85	2.15	
			Floodwall	1.05	1.57	1.30	1.60	2.12	1.85	2.15	
			Ramp	1.05	1.57	1.30	1.60	2.12	1.85	2.15	
4	Commercial Road / Bathhurst Dam	0	Floodwall	1.51	1.56	1.50	2.06	2.11	2.05	2.35	
			Upgrade and raising of existing structure	9.90	9.90	9.90	10.45	10.45	10.45	10.75	
			Existing Outfall	9.90	9.90	9.90	10.45	10.45	10.45	10.75	
			Floodwall	1.18	0.45	0.92	1.73	1.00	1.47	1.77	
			Floodwall	3.46		0.80	4.01	0.45	1.35	1.65	
			Floodwall	1.34	1.10	1.21	1.89	1.65	1.76	2.06	
			Ramp	0.93	1.12	1.02	1.48	1.67	1.57	1.87	
5	Clarence Road	0	Floodwall		0.45			1.00	0.25	0.50	
			Floodwall	0.44	2.30	1.29	0.99	2.85	1.84	2.09	
6	Cattle Market Road	1	Footbridge abutment	9.90	9.90	9.90	10.45	10.45	10.45	10.70	
			Floodwall		1.89	1.17	0.33	2.44	1.72	1.97	
			Floodwall		2.14	0.99	0.29	2.64	1.49	1.74	
7	Cattle Market Road	2	Floodwall		3.22	0.65		3.72	1.15	1.40	
			Use existing structure	9.85	9.85	9.85	10.35	10.35	10.35	10.60	

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)
7	St. Philips Marsh / Totterdown Defences		1 Ramp	0.55	1.26	0.97	1.10	1.81	1.52	1.87
			2 Floodwall	1.10	1.40	1.21	1.65	1.95	1.76	2.11
			3 Floodwall	1.28	2.18	1.59	1.83	2.73	2.14	2.49
			4 Floodwall	0.75	1.15	1.15	1.30	1.70	1.70	2.05
			5 Floodgate	1.85	2.08	2.01	2.40	2.63	2.56	2.91
			6 Floodwall	1.03	1.53	1.27	1.58	2.08	1.82	2.17
			7 Ramp / floodgate	0.95	1.22	1.02	1.50	1.77	1.57	1.92
			8 Floodwall	1.09	1.52	1.45	1.64	2.07	2.00	2.35
			9 Floodwall	1.32	1.47	1.42	1.87	2.02	1.97	2.32
			10 Floodwall	1.31	1.55	1.41	1.86	2.10	1.96	2.31
			11 Floodwall	0.87	1.57	1.41	1.42	2.12	1.96	2.31
			12 Floodwall	0.46	0.89	0.57	1.01	1.44	1.12	1.47
			13 Ramp	0.36	0.48	0.41	0.91	1.03	0.96	1.31
			14 Floodwall	0.32	0.37	0.35	0.87	0.92	0.90	1.25
			15 Floodwall	0.13	0.32	0.20	0.68	0.87	0.75	1.10
			16 Floodwall	0.26	0.34	0.31	0.81	0.89	0.86	1.21
			17 Floodwall	0.12	0.34	0.22	0.67	0.89	0.77	1.12
			18 Floodwall		0.73	0.33		1.28	0.88	1.23
			19 Existing bridge abutment	9.88	9.88	9.85	10.40	10.40	10.40	10.75
			20 Ramp		0.88	0.54		1.43	1.09	1.44
			21 Floodwall	0.51	0.65	0.57	1.06	1.20	1.12	1.47
			22 Floodwall	0.44	0.80	0.59	0.99	1.35	1.14	1.49
			23 Floodwall	0.68	0.83	0.77	1.23	1.38	1.32	1.67
			24 Floodwall	0.57	0.87	0.72	1.12	1.42	1.27	1.62
			25 Floodwall	0.58	0.84	0.67	1.13	1.39	1.22	1.57
			26 Floodwall	0.75	0.82	0.78	1.30	1.37	1.33	1.68
			27 Floodwall	0.53	1.59	1.13	1.08	2.14	1.68	2.03
			28 Floodwall	0.09	0.71	0.19	0.64	1.26	0.74	1.09
			29 Ramp	0.31	0.45	0.40	0.86	1.00	0.95	1.30
			30 Embankment	0.47	0.54	0.50	1.02	1.09	1.05	1.40
			31 Ramp	0.45	0.65	0.50	1.00	1.20	1.05	1.40
			32 Embankment	0.53	0.68	0.61	1.08	1.23	1.16	1.51
			33 Ramp	0.66	0.67	0.67	1.21	1.22	1.22	1.57
			34 Embankment	0.36	0.76	0.62	0.91	1.31	1.17	1.52
			35 Ramp	0.60	0.63	0.62	1.15	1.18	1.17	1.52
			36 Embankment		0.15	0.10	0.54	0.70	0.65	1.00
8	Netham Lock		1 Floodwall		1.84	0.86		2.34	1.36	1.66
			2a Floodwall	3.97	3.60	1.71	4.47	4.10	2.21	2.51
			2 Floodwall	3.97	3.60	1.71	4.47	4.10	2.21	2.51
			3 Floodwall		1.16	0.63	0.34	1.66	1.13	1.43
			4 Ramp	0.03	0.28	0.09	0.53	0.78	0.59	0.89
			5 [Removed from Scheme]	10.11	10.11	10.15	10.61	10.61	10.61	10.95
			6 Floodwall	1.05	3.28	2.76	1.55	3.78	3.26	3.56
			7 River Floodgate	6.17	7.09	6.63	6.67	7.59	7.13	7.43
			8 Floodwall		3.27	1.38	0.38	3.77	1.88	2.18
			9 [Removed from Scheme]	10.11	10.11	10.15	10.61	10.61	10.61	10.95
			10 Embankment		3.15	2.15		3.65	2.65	2.95
			11 Modifications to sluice structure at Netham Weir	10.11	10.11	10.15	10.61	10.61	10.61	10.95
12 Modifications to outfall from Avon side Road	10.11	10.11	10.15	10.61	10.61	10.61	10.95			

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)	
10	Bower Ashton		1a Floodwall		1.84	0.56		2.44	1.16	1.46	
			1b Embankment		1.84	0.56		2.44	1.16	1.46	
			1c Existing Outfall	9.90	9.90	9.90	10.50	10.50	10.50	10.80	
			2 Existing structure	9.90			10.50	10.50	10.50	10.80	
			3 Embankment	0.56	1.49	0.95	1.16	2.09	1.55	1.85	
			4 Floodgate	0.23	0.97	0.59	0.83	1.57	1.19	1.49	
			4a Existing Outfall	9.90	9.90	9.90	10.50	10.50	10.50	10.80	
			5 Embankment		1.65	0.43		2.25	1.03	1.33	
			13 Totterdown South Defences	1 Existing road - no work	0.00	0.00	0.00	10.40	10.40	10.40	10.70
			2 Floodwall		1.82			2.37			
14	Feeder Road		3 Raising existing structure	0.10	4.77	2.63	0.65	5.32	3.18	3.48	
			1 Floodwall		1.65	0.09		1.85	0.29	0.54	
			2 No work	8.45	8.45	8.45	8.65	8.65	8.65	8.90	
15	St. Anne's North Bank		3 Floodwall	0.36	1.68	1.05	0.56	1.88	1.25	1.50	
			1 Floodwall	0.97	1.39	1.19	1.32	1.74	1.54	1.89	
			2 Floodgate	0.93	1.21	1.10	1.28	1.56	1.45	1.80	
			3 Floodwall		4.14	1.60	0.24	4.49	1.95	2.30	
			4 Floodgate		1.64	0.64		1.99	0.99	1.34	
16	St. Anne's South Bank		5 Floodwall		1.64	0.64		1.99	0.99	1.34	
			1 Floodwall	0.47	3.66	1.15	0.82	4.01	1.50	1.85	
			2 Floodwall	0.47	3.66	1.15	0.82	4.01	1.50	1.85	
DM	City Centre Detriment		10 Raise Defence		0.10	0.00	0.40	0.60	0.50	0.50	
			11 Embankment	0.28	0.52	0.40	0.28	0.52	0.40	0.40	
			12 Embankment	3.30	3.50	3.40	3.30	3.50	3.40	3.40	
			13 Upgrade to existing structure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			14 Embankment	0.00	0.00	0.00	0.00	0.00	0.75	0.00	
			15 Upgrade to existing structure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Downstream	Detriment		16 Floodwall	0.63	3.81	1.30	0.80	3.98	1.48	1.68	
			1 Embankment	0.42	0.90	0.66	1.07	1.55	1.31	1.56	
			2 Raise Defence	0.48	0.50	0.49	1.13	1.15	1.14	1.39	
			3 Raise Defence	0.55	0.61	0.58	1.20	1.26	1.23	1.48	
			4 Raise Defence	0.32	0.61	0.47	0.97	1.26	1.12	1.37	
			5 Raise Defence		0.09		0.37	0.69	0.53	0.88	
			5b Raise Defence		0.09		0.37	0.69	0.53	0.88	
			6 Raise Defence	0.14	0.39	0.26	0.74	0.99	0.87	1.22	
			6b Floodwall	0.14	0.39	0.26	0.74	0.99	0.87	1.22	
			7 Embankment	1.51	2.09	1.80	2.11	2.69	2.40	2.75	
			7b Floodwall	1.51	2.09	1.80	2.11	2.69	2.40	2.75	
			8 Embankment		2.20	0.10		2.70	0.60	0.90	
			9 Embankment		2.20	0.10		2.70	0.60	0.90	
Upstream of A4174	Detriment	17 Embankment	0.00	0.00	1.00	0.00	0.00	1.50	1.50		

Defence heights for the 200 year SoP

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)
1	Entrance Lock / Western Harbour		1 Floodwall				0.19	0.47	0.31	0.61
			2 Road Raising and floodgate		1.79	0.77	0.47	2.39	1.37	1.67
			3 Floodwall	1.79	4.68	3.04	2.39	5.28	3.64	3.94
			4 Ramp / floodgate / steps	3.90	5.02	4.67	4.50	5.62	5.27	5.57
			5 Lock gate	4.87	5.12	5.04	5.47	5.72	5.64	5.94
			6 Property Level Protection	10.05	10.05	10.05	10.65	10.65	10.65	10.95
			7 Property Level Protection	10.05	10.05	10.05	10.65	10.65	10.65	10.95
			8 Floodwall	1.78	6.14	2.92	2.38	6.74	3.52	3.82
			9 Upgrade and raising of existing structure	3.87	4.67	4.08	4.47	5.27	4.68	4.98
			10 Ramp	1.11	1.23	1.15	1.71	1.83	1.75	2.05
			11 Floodwall	0.98	1.83	1.46	1.58	2.43	2.06	2.36
			12 Floodwall	1.10	4.73	2.16	1.70	5.33	2.76	3.06
			13 Floodwall	0.85	1.55	1.13	1.45	2.15	1.73	2.03
			14 Use existing structure	10.05	10.05	10.05	10.65	10.65	10.65	10.95
			15 Ramp	1.02	1.51	1.25	1.62	2.11	1.85	2.15
			16 Floodwall	0.60	1.55	1.32	1.20	2.15	1.92	2.22
			17 Ramp	0.47	0.82	0.61	1.07	1.42	1.21	1.51
			18 Floodwall	0.81	2.17	1.50	1.41	2.77	2.10	2.40
			19 Ramp	1.14	2.17	1.64	1.74	2.77	2.24	2.54
			20 Floodgate	1.64	1.64	1.64	2.24	2.24	2.24	2.54
			21 Floodwall	1.06	1.88	1.65	1.66	2.48	2.25	2.55
			22 Underfall Yard Sluice	10.05	10.05	10.05	10.65	10.65	10.65	10.95
2	Cumberland Road		0 Existing Outfall	10.10	10.10	10.10	10.65	10.65	10.65	10.95
			1 Floodwall	1.20	1.64	1.36	1.75	2.19	1.91	2.21
			2 Floodwall	1.37	1.46	1.42	1.92	2.01	1.97	2.27
			3 Floodwall	0.93	1.36	1.19	1.48	1.91	1.74	2.04
			4 Floodwall		1.47	0.81	0.31	2.02	1.36	1.66
			5 Raise Defence	1.00	1.46	1.25	1.55	2.01	1.80	2.10
6 Floodwall	1.13	1.63	1.40	1.68	2.18	1.95	2.25			
3	Cumberland Rd East Defence		1 Floodgate	1.25	1.77	1.50	1.80	2.32	2.05	2.40
			Floodwall	1.25	1.77	1.50	1.80	2.32	2.05	2.40
			2 Ramp	1.25	1.77	1.50	1.80	2.32	2.05	2.40
4	Commercial Road / Bathurst Dam		0 Floodwall	1.76	1.81	1.75	2.31	2.36	2.30	2.60
			1 Upgrade and raising of existing structure	10.15	10.15	10.15	10.70	10.70	10.70	11.00
			1a Existing Outfall	10.15	10.15	10.15	10.70	10.70	10.70	11.00
			2a Floodwall	1.43	0.70	1.17	1.98	1.25	1.72	2.02
			2 Floodwall	3.71	0.15	1.05	4.26	0.70	1.60	1.90
			3 Floodwall	1.59	1.35	1.46	2.14	1.90	2.01	2.31
			4 Ramp	1.18	1.37	1.27	1.73	1.92	1.82	2.12
5 Floodwall	1.08	2.19	1.53	1.63	2.74	2.08	2.38			
6 Floodwall	0.96	2.24	1.51	1.51	2.79	2.06	2.36			
5	Clarence Road		0 Floodwall		0.80	0.05		1.25	0.50	0.80
			1 Floodwall	0.79	2.65	1.64	1.24	3.10	2.09	2.39
			2 Footbridge abutment	10.25	10.25	10.25	10.70	10.70	10.70	11.00
3 Floodwall	0.13	2.24	1.52	0.58	2.69	1.97	2.27			
6	Cattle Market Road		1 Floodwall	0.14	2.49	1.34	0.64	2.99	1.84	2.14
			2 Floodwall		3.57	1.00		4.07	1.50	1.80
			3 Use existing structure	10.20	10.20	10.20	10.70	10.70	10.70	11.00

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)
7	St. Philips Marsh / Totterdown Defences		1 Ramp	0.95	1.66	1.37	1.45	2.16	1.87	2.17
			2 Floodwall	1.50	1.80	1.61	2.00	2.30	2.11	2.41
			3 Floodwall	1.68	2.58	1.99	2.18	3.08	2.49	2.79
			4 Floodwall	1.15	1.55	1.55	1.65	2.05	2.05	2.35
			5 Floodgate	2.25	2.48	2.41	2.75	2.98	2.91	3.21
			6 Floodwall	1.43	1.93	1.67	1.93	2.43	2.17	2.47
			7 Ramp / floodgate	1.35	1.62	1.42	1.85	2.12	1.92	2.22
			8 Floodwall	1.49	1.92	1.85	1.99	2.42	2.35	2.65
			9 Floodwall	1.72	1.87	1.82	2.22	2.37	2.32	2.62
			10 Floodwall	1.71	1.95	1.81	2.21	2.45	2.31	2.61
			11 Floodwall	1.27	1.97	1.81	1.77	2.47	2.31	2.61
			12 Floodwall	0.86	1.29	0.97	1.36	1.79	1.47	1.77
			13 Ramp	0.76	0.88	0.81	1.26	1.38	1.31	1.61
			14 Floodwall	0.72	0.77	0.75	1.22	1.27	1.25	1.55
			15 Floodwall	0.53	0.72	0.60	1.03	1.22	1.10	1.40
			16 Floodwall	0.66	0.74	0.71	1.16	1.24	1.21	1.51
			17 Floodwall	0.52	0.74	0.62	1.02	1.24	1.12	1.42
			18 Floodwall		1.13	0.73	0.10	1.63	1.23	1.53
			19 Existing bridge abutment	10.25	10.25	10.25	10.75	10.75	10.75	11.05
			20 Ramp		1.28	0.94	0.25	1.78	1.44	1.74
			21 Floodwall	0.91	1.05	0.97	1.41	1.55	1.47	1.77
			22 Floodwall	0.84	1.20	0.99	1.34	1.70	1.49	1.79
			23 Floodwall	1.08	1.23	1.17	1.58	1.73	1.67	1.97
			24 Floodwall	0.97	1.27	1.12	1.47	1.77	1.62	1.92
			25 Floodwall	0.98	1.24	1.07	1.48	1.74	1.57	1.87
			26 Floodwall	1.15	1.22	1.18	1.65	1.72	1.68	1.98
			27 Floodwall	0.93	1.99	1.53	1.43	2.49	2.03	2.33
			28 Floodwall	0.49	1.11	0.59	0.99	1.61	1.09	1.39
			29 Ramp	0.71	0.85	0.80	1.21	1.35	1.30	1.60
			30 Embankment	0.87	0.94	0.90	1.37	1.44	1.40	1.70
			31 Ramp	0.85	1.05	0.90	1.35	1.55	1.40	1.70
			32 Embankment	0.93	1.08	1.01	1.43	1.58	1.51	1.81
			33 Ramp	1.06	1.07	1.07	1.56	1.57	1.57	1.87
			34 Embankment	0.76	1.16	1.02	1.26	1.66	1.52	1.82
			35 Ramp	1.00	1.03	1.02	1.50	1.53	1.52	1.82
			36 Embankment	0.39	0.55	0.50	0.89	1.05	1.00	1.30
8	Netham Lock		1 Floodwall		2.09	1.11		2.49	1.51	1.96
			2a Floodwall	4.22	3.85	1.96	4.62	4.25	2.36	2.81
			2 Floodwall	4.22	3.85	1.96	4.62	4.25	2.36	2.81
			3 Floodwall	0.09	1.41	0.88	0.49	1.81	1.28	1.73
			4 Ramp	0.28	0.53	0.34	0.68	0.93	0.74	1.19
			5 [Removed from Scheme]	10.40	10.40	10.40	10.80	10.80	10.80	11.25
			6 Floodwall	1.30	3.53	3.01	1.70	3.93	3.41	3.86
			7 River Floodgate	6.42	7.34	6.88	6.82	7.74	7.28	7.73
			8 Floodwall	0.13	3.52	1.63	0.53	3.92	2.03	2.48
			9 [Removed from Scheme]	10.40	10.40	10.40	10.80	10.80	10.80	11.25
			10 Embankment		3.40	2.40		3.80	2.80	3.25
			11 Modifications to sluice structure at Netham Weir	10.40	10.40	10.40	10.80	10.80	10.80	11.25
12 Modifications to outfall from Avon side Road	10.40	10.40	10.40	10.80	10.80	10.80	11.25			

Reach	Reach Title	Section	Defence type	Arup FCERM 2065 Min defence height (m)	Arup FCERM 2065 Max defence height (m)	Arup FCERM 2065 Average defence height (m)	Arup FCERM 2125 Min defence height (m)	Arup FCERM 2125 Max defence height (m)	Arup FCERM 2125 Average defence height (m)	Arup NPPF 2125 Mean defence height (m)	
10	Bower Ashton		1a Floodwall		1.99	0.71		2.59	1.31	1.61	
			1b Embankment		1.99	0.71		2.59	1.31	1.61	
			1c Existing Outfall	10.05	10.05	10.05	10.65	10.65	10.65	10.95	10.95
			2 Existing structure	10.05			10.65	10.65	10.65	10.95	10.95
			3 Embankment	0.71	1.64	1.10	1.31	2.24	1.70	2.00	2.00
			4 Floodgate	0.38	1.12	0.74	0.98	1.72	1.34	1.64	
			4a Existing Outfall	10.05	10.05	10.05	10.65	10.65	10.65	10.95	10.95
			5 Embankment		1.80	0.58		2.40	1.18	1.48	1.48
			1 Existing road - no work	0.00	0.00	0.00	10.75	10.75	10.75	11.05	11.05
			2 Floodwall		2.22			2.72		0.22	0.22
13	Totterdown South Defences		3 Raising existing structure	0.50	5.17	3.03	1.00	5.67	3.53	3.83	
			1 Floodwall		1.95	0.39		2.25	0.69	0.89	
			2 No work	8.75	8.75	8.75	9.05	9.05	9.05	9.25	9.25
14	Feeder Road		3 Floodwall	0.66	1.98	1.35	0.96	2.28	1.65	1.85	
			1 Floodwall	1.27	1.69	1.49	1.67	2.09	1.89	2.24	
			2 Floodgate	1.23	1.51	1.40	1.63	1.91	1.80	2.15	
15	St. Anne's North Bank		3 Floodwall	0.19	4.44	1.90	0.59	4.84	2.30	2.65	
			4 Floodgate		1.94	0.94		2.34	1.34	1.69	
			5 Floodwall		1.94	0.94		2.34	1.34	1.69	
			1 Floodwall	0.77	3.96	1.45	1.17	4.36	1.85	2.20	
			2 Floodwall	0.77	3.96	1.45	1.17	4.36	1.85	2.20	
DM	City Centre Detriment		10 Raise Defence		0.10	0.00	0.40	0.60	0.50	0.50	
			11 Embankment	0.28	0.52	0.40	0.28	0.52	0.40	0.40	
			12 Embankment	3.30	3.50	3.40	3.30	3.50	3.40	3.40	
			13 Upgrade to existing structure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			14 Embankment	0.00	0.00	0.00	0.00	0.00	0.75	0.00	
			15 Upgrade to existing structure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			16 Floodwall	0.78	3.96	1.45	1.08	4.27	1.76	2.10	
Downstream	Detriment		1 Embankment	0.57	1.05	0.81	1.12	1.60	1.36	1.66	
			2 Raise Defence	0.63	0.65	0.64	1.18	1.20	1.19	1.49	
			3 Raise Defence	0.70	0.76	0.73	1.25	1.31	1.28	1.58	
			4 Raise Defence	0.47	0.76	0.62	1.02	1.31	1.17	1.47	
			5 Raise Defence		0.24	0.08	0.52	0.84	0.68	0.98	
			5b Raise Defence		0.24	0.08	0.52	0.84	0.68	0.98	
			6 Raise Defence	0.29	0.54	0.41	0.89	1.14	1.02	1.32	
			6b Floodwall	0.29	0.54	0.41	0.89	1.14	1.02	1.32	
			7 Embankment	1.66	2.24	1.95	2.26	2.84	2.55	2.85	
			7b Floodwall	1.66	2.24	1.95	2.26	2.84	2.55	2.85	
			8 Embankment		2.30	0.20		2.85	0.75	1.05	
			9 Embankment		2.30	0.20		2.85	0.75	1.05	
			Upstream of A4174	Detriment	17 Embankment	0.00	0.00	1.00	0.00	0.00	1.50

Appendix D – Scenarios and Costing Information

Scenario	Phase 1 (2020s)	Phase 2 (2065)
5C	Construct to FCERM 2065 50yr SoP by 2025. Low Public Realm rate	Raise in 2065 to FCERM 2125 50yr SoP Low Public Realm rate
6C	Construct to FCERM 2065 75yr SoP by 2025. Low Public Realm rate	Raise in 2065 to FCERM 2125 75yr SoP Low Public Realm rate
7C	Construct to FCERM 2065 100yr SoP by 2025. Low Public Realm rate	Raise in 2065 to FCERM 2125 100yr SoP Low Public Realm rate
8C	Construct to FCERM 2065 200yr SoP by 2025. Low Public Realm rate	Raise in 2065 to FCERM 2125 200yr SoP Low Public Realm rate
8C_B	Construct to FCERM 2065 200yr SoP by 2025. High public realm rate	Raise in 2065 to FCERM 2125 200yr SoP. High public realm rate
9A	Construct to 2065 NPPF 100/200yr SoP without freeboard by 2025 everywhere. Low Public Realm rate	Raise in 2065 to 2125 NPPF 100/200yr SoP without freeboard everywhere Low Public Realm rate

Option 5C

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
1-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	50yr	N/A			50yr
1-2	Ramp	FCERM 2065		50yr	Floodgate	FCERM 2125		50yr
1-3	RC wall on minipiles	FCERM 2065	Low	50yr	N/A			50yr
1-4	Floodgate	FCERM 2065		50yr	N/A			50yr
1-5	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
1-6	[no work]			50yr	N/A			50yr
1-7	[no work]			50yr	N/A			50yr
1-8	Terraced Wall on minipiles	FCERM 2065	High	50yr	Wall raising: Glazed	FCERM 2125		50yr
1-9	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
1-10	Ramp	FCERM 2065		50yr	Floodgate	FCERM 2125		50yr
1-11	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	50yr	N/A			50yr
1-12	1500d 19mL Contig Piled Wall	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
1-13	RC wall on minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
1-14	Use existing structure	FCERM 2065		50yr	N/A			50yr
1-15	Ramp	FCERM 2065		50yr	N/A			50yr
1-16	RC wall on minipiles	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
1-17	Ramp	FCERM 2065		50yr	N/A			50yr
1-18	RC wall on minipiles	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
1-19	Ramp	FCERM 2065		50yr	N/A			50yr
1-20	Floodgate	FCERM 2065		50yr	N/A			50yr
1-21	RC wall on minipiles	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
1-22	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
2-0	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
2-1	Choc. Path remedials - Wall on piles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
2-2	Choc. Path remedials - Wall on piles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
2-3	Choc. Path remedials - Wall on piles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
2-4	Choc. Path remedials - Wall on piles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
2-5	Wall raising	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
2-6	Choc. Path remedials - Wall on piles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
3-1	Floodgate	FCERM 2065		50yr	N/A			50yr
3-1	Reinforced Concrete wall (>1.2m)	FCERM 2065		50yr	Wall raising			50yr
3-2	Ramp	FCERM 2065		50yr	N/A			50yr
4-0	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
4-1	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
4-1a	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
4-2	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
4-2a	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
4-3	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
4-4	Ramp	FCERM 2065		50yr	N/A			50yr
4-5	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
4-6	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
5-0	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
5-1	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
5-2	Use existing structure	check		50yr	N/A			50yr
5-3	Floodwall on piles (3)	FCERM 2065	Low	50yr	Wall raising: Glazed	FCERM 2125		50yr
6-1	RC wall on minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
6-2	RC wall on minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
6-3	Use existing structure	FCERM 2065		50yr	N/A			50yr
7-1	Ramp	FCERM 2065		50yr	Ramp	FCERM 2125		50yr
7-2	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-3	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-4	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
7-5	Floodgate	FCERM 2065		50yr	N/A			50yr
7-6	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-7	Ramp	FCERM 2065		50yr	Floodgate	FCERM 2125		50yr
7-8	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-9	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-10	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-11	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-12	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-13	Ramp	FCERM 2065		50yr	Ramp	FCERM 2125		50yr
7-14	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-15	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-16	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-17	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-18	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-19	Use existing structure	check		50yr	N/A			50yr
7-20	Ramp	FCERM 2065		50yr	Ramp	FCERM 2125		50yr
7-21	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-22	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-23	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-24	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-25	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-26	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-27	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-28	RC wall on angled minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
7-29	Ramp	FCERM 2065		50yr	Ramp	FCERM 2125		50yr
7-30	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
7-31	Ramp	FCERM 2065		50yr	Ramp	FCERM 2125		50yr
7-32	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
7-33	Ramp	FCERM 2065		50yr	Ramp	FCERM 2125		50yr
7-34	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
7-35	Ramp	FCERM 2065		50yr	Ramp	FCERM 2125		50yr
7-36	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
8-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
8-2	Sheet Piled Wall (>100m length)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
8-2a	Sheet Piled Wall (<100m length)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
8-3	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
8-4	Ramp	FCERM 2065		50yr	N/A			50yr
8-5	[Removed from Scheme]	check		50yr	N/A			50yr
8-6	RC wall on minipiles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
8-7	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
8-8	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
8-9	[Removed from Scheme]	check		50yr	N/A			50yr
8-10	embankment	FCERM 2065		50yr	N/A			50yr
8-11	[lump sum item]	FCERM 2065		50yr	N/A			50yr
8-12	[lump sum item]	FCERM 2065		50yr	N/A			50yr
10-1a	1500d 23mL Contig Piled Wall	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
10-1b	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
10-1c	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
10-2	Use existing structure	check		50yr	N/A			50yr
10-3	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
10-4	Floodgate	FCERM 2065		50yr	N/A			50yr
10-4a	[Lump sum item]	FCERM 2065		50yr	N/A			50yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
10-5	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
13-1	[no work]			50yr	N/A			50yr
13-2	RC wall on minipiles	FCERM 2065	Low	50yr	N/A			50yr
13-3	N/A		Low	50yr	Wall raising	FCERM 2125	Low	50yr
14-1	Double Raked Piles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
14-2	[no work]	FCERM 2065		50yr	N/A	FCERM 2125		50yr
14-3	Double Raked Piles	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
15-1	Sheet Piled Wall (<100m length)	FCERM 2065	Low	50yr	N/A			50yr
15-2	Floodgate	FCERM 2065		50yr	N/A			50yr
15-3	Sheet Piled Wall (>100m length)	FCERM 2065	Low	50yr	N/A			50yr
15-4	Floodgate	FCERM 2065		50yr	N/A			50yr
15-5	Sheet Piled Wall (>100m length)	FCERM 2065	Low	50yr	N/A			50yr
16-1	Sheet Piled Wall (>100m length)	FCERM 2065	Low	50yr	N/A			50yr
16-2	[no work]		Low	50yr	Sheet Piled Wall (>100m)	FCERM 2125	Low	50yr
DM-1	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
DM-2	Wall raising	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
DM-3	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
DM-4	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
DM-5	N/A			50yr	Embankment	FCERM 2125		50yr
DM-5b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
DM-6	Wall raising	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
DM-6b	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
DM-7	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
DM-7b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
DM-8	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
DM-9	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr
DM10	N/A			50yr	Wall raising	FCERM 2125		50yr
DM11	N/A			50yr	Embankment	FCERM 2125		50yr
DM12	Embankment	FCERM 2065		50yr	N/A			50yr
DM13	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
DM14	N/A	FCERM 2065		50yr	Wall raising	FCERM 2125		50yr
DM15	[Lump sum item]	FCERM 2065		50yr	N/A			50yr
DM16	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	50yr	Wall raising	FCERM 2125		50yr
DM17	Embankment	FCERM 2065		50yr	Embankment	FCERM 2125		50yr

Headline Arup Costs - Option 5C

Areas	Reaches	Reach Title	Protection Level	Placemaking	Return Period	Length of Defences built in 2024 (m)	CAPEX in 2024 (2019 equivalent)		Total CAPEX Cost in 2024 (2019 equivalent + other Costs and Fees + Optimism bias)	Length of Defences built in 2065 (m)	CAPEX in 2065 (2019 equivalent + service diversions)		Total CAPEX Cost in 2065 (2019 equivalent + other Costs & Fees + Optimism bias)
							CAPEX in 2024 (2019 equivalent)	+ service diversions			CAPEX in 2065 (2019 equivalent)	+ service diversions	
Western Harbour	1	Entrance Lock / Western Harbour	FCERM 2065 & FCERM 2125	Low (except section 1-8)	50yr	1350	£ 14,591,484	£ 15,321,058	£ 29,263,222	909	£ 1,911,297	£ 2,006,862	£ 3,833,107
Western Corridor	2	Cumberland Road	FCERM 2065 & FCERM 2125	Low	50yr	850	£ 34,123,058	£ 35,829,210	£ 63,489,361	850	£ 1,311,510	£ 1,377,085	£ 2,440,195
Western Corridor	3	Cumberland Rd East Defence	FCERM 2065 & FCERM 2125	Low	50yr	16	£ 183,345	£ 192,512	£ 367,698	0	£ -	£ -	£ -
Western Corridor	4	Commercial Road / Bathurst Dam	FCERM 2065 & FCERM 2125	Low	50yr	310	£ 5,697,654	£ 5,982,536	£ 11,426,644	288	£ 539,626	£ 566,607	£ 1,082,220
Western Corridor	5	Clarence Road	FCERM 2065 & FCERM 2125	Low	50yr	560	£ 9,778,139	£ 10,267,046	£ 19,610,058	570	£ 811,805	£ 852,395	£ 1,628,075
Eastern Corridor	6	Cattle Market Road	FCERM 2065 & FCERM 2125	Low	50yr	250	£ 1,831,443	£ 1,923,015	£ 3,672,959	250	£ 386,988	£ 406,338	£ 776,105
Eastern Corridor	7	St. Philips Marsh / Totterdown Defences	FCERM 2065 & FCERM 2125	Low	50yr	1488	£ 13,098,234	£ 13,753,145	£ 26,268,508	1483	£ 2,378,009	£ 2,496,909	£ 4,769,097
Netham Lock	8	Netham Lock	FCERM 2065 & FCERM 2125	Low	50yr	705	£ 7,680,417	£ 8,064,438	£ 15,403,077	679	£ 1,071,731	£ 1,125,318	£ 2,149,357
Western Harbour	10	Bower Ashton	FCERM 2065 & FCERM 2125	Low	50yr	940	£ 2,639,465	£ 2,771,438	£ 5,293,447	920	£ 836,451	£ 878,274	£ 1,677,503
Eastern Corridor	13	Totterdown South Defences	FCERM 2065 & FCERM 2125	Low	50yr	0	£ -	£ -	£ -	440	£ 1,202,317	£ 1,262,432	£ 2,411,246
Feeder Road	14	Feeder Road	FCERM 2065 & FCERM 2125	Low	50yr	730	£ 3,824,880	£ 4,016,124	£ 7,670,797	0	£ -	£ -	£ -
St. Annes	15	St. Anne's North Bank	FCERM 2065 & FCERM 2125	Low	50yr	1414	£ 10,843,116	£ 11,385,272	£ 21,745,869	0	£ -	£ -	£ -
St. Annes	16	St. Anne's South Bank	FCERM 2065 & FCERM 2125	Low	50yr	1010	£ 7,255,052	£ 7,617,804	£ 14,550,006	0	£ -	£ -	£ -
Detriment Mitigations	DM	Downstream, City Centre and Upstream of A417 Detriment	FCERM 2065 & FCERM 2125	Low	50yr	5239	£ 6,091,394	£ 6,395,964	£ 12,216,291	6589	£ 3,157,343	£ 3,315,210	£ 6,332,051
Total						14862	£ 117,637,680	£ 123,519,564	£ 230,977,936	12978	£ 13,607,077	£ 14,287,431	£ 27,098,956

Option 6C

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
1-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	75yr	N/A			75yr
1-2	Ramp	FCERM 2065		75yr	Floodgate	FCERM 2125		75yr
1-3	RC wall on minipiles	FCERM 2065	Low	75yr	N/A			75yr
1-4	Floodgate	FCERM 2065		75yr	N/A			75yr
1-5	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
1-6	[no work]			75yr	N/A			75yr
1-7	[no work]			75yr	N/A			75yr
1-8	Terraced Wall on minipiles	FCERM 2065	High	75yr	Wall raising: Glazed	FCERM 2125		75yr
1-9	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
1-10	Ramp	FCERM 2065		75yr	Floodgate	FCERM 2125		75yr
1-11	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	75yr	N/A			75yr
1-12	1500d 19mL Contig Piled Wall	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
1-13	RC wall on minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
1-14	Use existing structure	FCERM 2065		75yr	N/A			75yr
1-15	Ramp	FCERM 2065		75yr	N/A			75yr
1-16	RC wall on minipiles	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
1-17	Ramp	FCERM 2065		75yr	N/A			75yr
1-18	RC wall on minipiles	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
1-19	Ramp	FCERM 2065		75yr	N/A			75yr
1-20	Floodgate	FCERM 2065		75yr	N/A			75yr
1-21	RC wall on minipiles	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
1-22	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
2-0	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
2-1	Choc. Path remedials - Wall on piles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
2-2	Choc. Path remedials - Wall on piles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
2-3	Choc. Path remedials - Wall on piles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
2-4	Choc. Path remedials - Wall on piles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
2-5	Wall raising	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
2-6	Choc. Path remedials - Wall on piles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
3-1	Floodgate	FCERM 2065		75yr	N/A			75yr
3-1	Reinforced Concrete wall (>1.2m)	FCERM 2065		75yr	Wall raising			75yr
3-2	Ramp	FCERM 2065		75yr	N/A			75yr
4-0	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
4-1	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
4-1a	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
4-2	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
4-2a	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
4-3	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
4-4	Ramp	FCERM 2065		75yr	N/A			75yr
4-5	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
4-6	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
5-0	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
5-1	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
5-2	Use existing structure	check		75yr	N/A			75yr
5-3	Floodwall on piles (3)	FCERM 2065	Low	75yr	Wall raising: Glazed	FCERM 2125		75yr
6-1	RC wall on minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
6-2	RC wall on minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
6-3	Use existing structure	FCERM 2065		75yr	N/A			75yr
7-1	Ramp	FCERM 2065		75yr	Ramp	FCERM 2125		75yr
7-2	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-3	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-4	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
7-5	Floodgate	FCERM 2065		75yr	N/A			75yr
7-6	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-7	Ramp	FCERM 2065		75yr	Floodgate	FCERM 2125		75yr
7-8	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-9	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-10	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-11	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-12	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-13	Ramp	FCERM 2065		75yr	Ramp	FCERM 2125		75yr
7-14	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-15	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-16	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-17	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-18	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-19	Use existing structure	check		75yr	N/A			75yr
7-20	Ramp	FCERM 2065		75yr	Ramp	FCERM 2125		75yr
7-21	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-22	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-23	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-24	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-25	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-26	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-27	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-28	RC wall on angled minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
7-29	Ramp	FCERM 2065		75yr	Ramp	FCERM 2125		75yr
7-30	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
7-31	Ramp	FCERM 2065		75yr	Ramp	FCERM 2125		75yr
7-32	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
7-33	Ramp	FCERM 2065		75yr	Ramp	FCERM 2125		75yr
7-34	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
7-35	Ramp	FCERM 2065		75yr	Ramp	FCERM 2125		75yr
7-36	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
8-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
8-2	Sheet Piled Wall (>100m length)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
8-2a	Sheet Piled Wall (<100m length)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
8-3	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
8-4	Ramp	FCERM 2065		75yr	N/A			75yr
8-5	[Removed from Scheme]	check		75yr	N/A			75yr
8-6	RC wall on minipiles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
8-7	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
8-8	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
8-9	[Removed from Scheme]	check		75yr	N/A			75yr
8-10	embankment	FCERM 2065		75yr	N/A			75yr
8-11	[lump sum item]	FCERM 2065		75yr	N/A			75yr
8-12	[lump sum item]	FCERM 2065		75yr	N/A			75yr
10-1a	1500d 23mL Contig Piled Wall	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
10-1b	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
10-1c	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
10-2	Use existing structure	check		75yr	N/A			75yr
10-3	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
10-4	Floodgate	FCERM 2065		75yr	N/A			75yr
10-4a	[Lump sum item]	FCERM 2065		75yr	N/A			75yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
10-5	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
13-1	[no work]			75yr	N/A			75yr
13-2	RC wall on minipiles	FCERM 2065	Low	75yr	N/A			75yr
13-3	N/A		Low	75yr	Wall raising	FCERM 2125	Low	75yr
14-1	Double Raked Piles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
14-2	[no work]	FCERM 2065		75yr	N/A	FCERM 2125		75yr
14-3	Double Raked Piles	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
15-1	Sheet Piled Wall (<100m length)	FCERM 2065	Low	75yr	N/A			75yr
15-2	Floodgate	FCERM 2065		75yr	N/A			75yr
15-3	Sheet Piled Wall (>100m length)	FCERM 2065	Low	75yr	N/A			75yr
15-4	Floodgate	FCERM 2065		75yr	N/A			75yr
15-5	Sheet Piled Wall (>100m length)	FCERM 2065	Low	75yr	N/A			75yr
16-1	Sheet Piled Wall (>100m length)	FCERM 2065	Low	75yr	N/A			75yr
16-2	[no work]		Low	75yr	Sheet Piled Wall (>100m)	FCERM 2125	Low	75yr
DM-1	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
DM-2	Wall raising	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
DM-3	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
DM-4	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
DM-5	N/A			75yr	Embankment	FCERM 2125		75yr
DM-5b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
DM-6	Wall raising	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
DM-6b	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
DM-7	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
DM-7b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
DM-8	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
DM-9	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr
DM10	N/A			75yr	Wall raising	FCERM 2125		75yr
DM11	N/A			75yr	Embankment	FCERM 2125		75yr
DM12	Embankment	FCERM 2065		75yr	N/A			75yr
DM13	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
DM14	N/A	FCERM 2065		75yr	Wall raising	FCERM 2125		75yr
DM15	[Lump sum item]	FCERM 2065		75yr	N/A			75yr
DM16	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	75yr	Wall raising	FCERM 2125		75yr
DM17	Embankment	FCERM 2065		75yr	Embankment	FCERM 2125		75yr

Headline Arup Costs - Option 6C

Areas	Reaches	Reach Title	Protection Level	Placemaking	Return Period	CAPEX in 2024				Total CAPEX Cost in 2065			
						Length of Defences built in 2024 (m)	CAPEX in 2024 (2019 equivalent)	+ service diversions	Total CAPEX Cost in 2024 (2019 equivalent + other Costs and Fees + Optimism bias)	Length of Defences built in 2065 (m)	CAPEX in 2065 (2019 equivalent)	CAPEX in 2065 (2019 equivalent + service diversions)	Total CAPEX Cost in 2065 (2019 equivalent + other Costs & Fees + Optimism bias)
Western Harbour	1	Entrance Lock / Western Harbour	FCERM 2065 & FCERM 2125	Low (except section 1-8)	75yr	1350	£ 14,619,084	£ 15,350,038	£ 29,318,572	909	£ 2,015,411	£ 2,116,182	£ 4,041,908
Western Corridor	2	Cumberland Road	FCERM 2065 & FCERM 2125	Low	75yr	850	£ 34,104,701	£ 35,809,936	£ 63,455,206	850	£ 1,293,733	£ 1,358,419	£ 2,407,119
Western Corridor	3	Cumberland Rd East Defence	FCERM 2065 & FCERM 2125	Low	75yr	16	£ 185,776	£ 195,065	£ 372,573	0	£ -	£ -	£ -
Western Corridor	4	Commercial Road / Bathurst Dam	FCERM 2065 & FCERM 2125	Low	75yr	310	£ 5,704,612	£ 5,989,842	£ 11,440,599	288	£ 542,543	£ 569,670	£ 1,088,070
Western Corridor	5	Clarence Road	FCERM 2065 & FCERM 2125	Low	75yr	560	£ 9,756,795	£ 10,244,635	£ 19,567,253	570	£ 887,187	£ 931,547	£ 1,779,255
Eastern Corridor	6	Cattle Market Road	FCERM 2065 & FCERM 2125	Low	75yr	250	£ 1,837,164	£ 1,929,022	£ 3,684,431	250	£ 388,821	£ 408,262	£ 779,781
Eastern Corridor	7	St. Philips Marsh / Totterdown Defences	FCERM 2065 & FCERM 2125	Low	75yr	1488	£ 13,157,860	£ 13,815,753	£ 26,388,088	1483	£ 2,464,563	£ 2,587,791	£ 4,942,681
Netham Lock	8	Netham Lock	FCERM 2065 & FCERM 2125	Low	75yr	715	£ 7,699,560	£ 8,084,538	£ 15,441,468	679	£ 1,081,689	£ 1,135,774	£ 2,169,328
Western Harbour	10	Bower Ashton	FCERM 2065 & FCERM 2125	Low	75yr	940	£ 2,675,295	£ 2,809,059	£ 5,365,303	920	£ 836,711	£ 878,547	£ 1,678,024
Eastern Corridor	13	Totterdown South Defences	FCERM 2065 & FCERM 2125	Low	75yr	0	£ -	£ -	£ -	440	£ 1,205,543	£ 1,265,820	£ 2,417,716
Feeder Road	14	Feeder Road	FCERM 2065 & FCERM 2125	Low	75yr	730	£ 3,824,880	£ 4,016,124	£ 7,670,797	880	£ 1,329,193	£ 1,395,652	£ 2,665,696
St. Annes	15	St. Anne's North Bank	FCERM 2065 & FCERM 2125	Low	75yr	1414	£ 10,843,116	£ 11,385,272	£ 21,745,869	0	£ -	£ -	£ -
St. Annes	16	St. Anne's South Bank	FCERM 2065 & FCERM 2125	Low	75yr	1010	£ 7,255,052	£ 7,617,804	£ 14,550,006	0	£ -	£ -	£ -
Detriment Mitigations	DM	Downstream, City Centre and Upstream of A417 Detriment	FCERM 2065 & FCERM 2125	Low	75yr	5379	£ 7,249,588	£ 7,612,068	£ 14,539,050	6729	£ 3,456,168	£ 3,628,976	£ 6,931,345
Total						15012	£ 118,913,481	£ 124,859,155	£ 233,539,216	13998	£ 15,501,563	£ 16,276,641	£ 30,900,922

Option 7C

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
1-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	100yr	N/A			100yr
1-2	Ramp	FCERM 2065		100yr	Floodgate	FCERM 2125		100yr
1-3	RC wall on minipiles	FCERM 2065	Low	100yr	N/A			100yr
1-4	Floodgate	FCERM 2065		100yr	N/A			100yr
1-5	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
1-6	[no work]			100yr	N/A			100yr
1-7	[no work]			100yr	N/A			100yr
1-8	Terraced Wall on minipiles	FCERM 2065	High	100yr	Wall raising: Glazed	FCERM 2125		100yr
1-9	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
1-10	Ramp	FCERM 2065		100yr	Floodgate	FCERM 2125		100yr
1-11	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	100yr	N/A			100yr
1-12	1500d 19mL Contig Piled Wall	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
1-13	RC wall on minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
1-14	Use existing structure	FCERM 2065		100yr	N/A			100yr
1-15	Ramp	FCERM 2065		100yr	N/A			100yr
1-16	RC wall on minipiles	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
1-17	Ramp	FCERM 2065		100yr	N/A			100yr
1-18	RC wall on minipiles	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
1-19	Ramp	FCERM 2065		100yr	N/A			100yr
1-20	Floodgate	FCERM 2065		100yr	N/A			100yr
1-21	RC wall on minipiles	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
1-22	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
2-0	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
2-1	Choc. Path remedials - Wall on piles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
2-2	Choc. Path remedials - Wall on piles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
2-3	Choc. Path remedials - Wall on piles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
2-4	Choc. Path remedials - Wall on piles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
2-5	Wall raising	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
2-6	Choc. Path remedials - Wall on piles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
3-1	Floodgate	FCERM 2065		100yr	N/A			100yr
3-1	Reinforced Concrete wall (>1.2m)	FCERM 2065		100yr	Wall raising			100yr
3-2	Ramp	FCERM 2065		100yr	N/A			100yr
4-0	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
4-1	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
4-1a	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
4-2	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
4-2a	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
4-3	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
4-4	Ramp	FCERM 2065		100yr	N/A			100yr
4-5	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
4-6	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
5-0	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
5-1	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
5-2	Use existing structure	check		100yr	N/A			100yr
5-3	Floodwall on piles (3)	FCERM 2065	Low	100yr	Wall raising: Glazed	FCERM 2125		100yr
6-1	RC wall on minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
6-2	RC wall on minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
6-3	Use existing structure	FCERM 2065		100yr	N/A			100yr
7-1	Ramp	FCERM 2065		100yr	Ramp	FCERM 2125		100yr
7-2	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-3	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-4	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
7-5	Floodgate	FCERM 2065		100yr	N/A			100yr
7-6	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-7	Ramp	FCERM 2065		100yr	Floodgate	FCERM 2125		100yr
7-8	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-9	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-10	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-11	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-12	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-13	Ramp	FCERM 2065		100yr	Ramp	FCERM 2125		100yr
7-14	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-15	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-16	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-17	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-18	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-19	Use existing structure	check		100yr	N/A			100yr
7-20	Ramp	FCERM 2065		100yr	Ramp	FCERM 2125		100yr
7-21	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-22	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-23	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-24	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-25	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-26	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-27	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-28	RC wall on angled minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
7-29	Ramp	FCERM 2065		100yr	Ramp	FCERM 2125		100yr
7-30	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
7-31	Ramp	FCERM 2065		100yr	Ramp	FCERM 2125		100yr
7-32	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
7-33	Ramp	FCERM 2065		100yr	Ramp	FCERM 2125		100yr
7-34	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
7-35	Ramp	FCERM 2065		100yr	Ramp	FCERM 2125		100yr
7-36	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
8-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
8-2	Sheet Piled Wall (>100m length)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
8-2a	Sheet Piled Wall (<100m length)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
8-3	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
8-4	Ramp	FCERM 2065		100yr	N/A			100yr
8-5	[Removed from Scheme]	check		100yr	N/A			100yr
8-6	RC wall on minipiles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
8-7	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
8-8	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
8-9	[Removed from Scheme]	check		100yr	N/A			100yr
8-10	embankment	FCERM 2065		100yr	N/A			100yr
8-11	[lump sum item]	FCERM 2065		100yr	N/A			100yr
8-12	[lump sum item]	FCERM 2065		100yr	N/A			100yr
10-1a	1500d 23mL Contig Piled Wall	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
10-1b	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
10-1c	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
10-2	Use existing structure	check		100yr	N/A			100yr
10-3	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
10-4	Floodgate	FCERM 2065		100yr	N/A			100yr
10-4a	[Lump sum item]	FCERM 2065		100yr	N/A			100yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
10-5	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
13-1	[no work]			100yr	N/A			100yr
13-2	RC wall on minipiles	FCERM 2065	Low	100yr	N/A			100yr
13-3	N/A		Low	100yr	Wall raising	FCERM 2125	Low	100yr
14-1	Double Raked Piles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
14-2	[no work]	FCERM 2065		100yr	N/A	FCERM 2125		100yr
14-3	Double Raked Piles	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
15-1	Sheet Piled Wall (<100m length)	FCERM 2065	Low	100yr	N/A			100yr
15-2	Floodgate	FCERM 2065		100yr	N/A			100yr
15-3	Sheet Piled Wall (>100m length)	FCERM 2065	Low	100yr	N/A			100yr
15-4	Floodgate	FCERM 2065		100yr	N/A			100yr
15-5	Sheet Piled Wall (>100m length)	FCERM 2065	Low	100yr	N/A			100yr
16-1	Sheet Piled Wall (>100m length)	FCERM 2065	Low	100yr	N/A			100yr
16-2	[no work]		Low	100yr	Sheet Piled Wall (>100m)	FCERM 2125	Low	100yr
DM-1	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
DM-2	Wall raising	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
DM-3	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
DM-4	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
DM-5	N/A			100yr	Embankment	FCERM 2125		100yr
DM-5b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
DM-6	Wall raising	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
DM-6b	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
DM-7	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
DM-7b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
DM-8	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
DM-9	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr
DM10	N/A			100yr	Wall raising	FCERM 2125		100yr
DM11	N/A			100yr	Embankment	FCERM 2125		100yr
DM12	Embankment	FCERM 2065		100yr	N/A			100yr
DM13	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
DM14	N/A	FCERM 2065		100yr	Wall raising	FCERM 2125		100yr
DM15	[Lump sum item]	FCERM 2065		100yr	N/A			100yr
DM16	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	100yr	Wall raising	FCERM 2125		100yr
DM17	Embankment	FCERM 2065		100yr	Embankment	FCERM 2125		100yr

Headline Arup Costs - Option 7C

Areas	Reaches	Reach Title	Protection Level	Placemaking	Return Period	CAPEX in 2024				CAPEX in 2065			
						Length of Defences built in 2024 (m)	CAPEX in 2024 (2019 equivalent)	+ service diversions	Total CAPEX Cost in 2024 (2019 equivalent + other Costs and Fees + Optimism bias)	Length of Defences built in 2065 (m)	CAPEX in 2065 (2019 equivalent)	+ service diversions	Total CAPEX Cost in 2065 (2019 equivalent + other Costs & Fees + Optimism bias)
Western Harbour	1	Entrance Lock / Western Harbour	FCERM 2065 & FCERM 2125	Low (except section 1-8)	100yr	1350	£ 14,659,580	£ 15,392,559	£ 29,399,787	909	£ 2,022,519	£ 2,123,645	£ 4,056,161
Western Corridor	2	Cumberland Road	FCERM 2065 & FCERM 2125	Low	100yr	850	£ 34,110,934	£ 35,816,480	£ 63,466,803	850	£ 1,299,966	£ 1,364,964	£ 2,418,716
Western Corridor	3	Cumberland Rd East Defence	FCERM 2065 & FCERM 2125	Low	100yr	16	£ 188,242	£ 197,654	£ 377,519	0	£ -	£ -	£ -
Western Corridor	4	Commercial Road / Bathurst Dam	FCERM 2065 & FCERM 2125	Low	100yr	310	£ 5,711,687	£ 5,997,271	£ 11,454,787	288	£ 545,460	£ 572,733	£ 1,093,919
Western Corridor	5	Clarence Road	FCERM 2065 & FCERM 2125	Low	100yr	560	£ 9,762,467	£ 10,250,590	£ 19,578,627	570	£ 887,188	£ 931,547	£ 1,779,255
Eastern Corridor	6	Cattle Market Road	FCERM 2065 & FCERM 2125	Low	100yr	250	£ 1,842,884	£ 1,935,028	£ 3,695,904	250	£ 373,504	£ 392,180	£ 749,063
Eastern Corridor	7	St. Philips Marsh / Totterdown Defences	FCERM 2065 & FCERM 2125	Low	100yr	1488	£ 13,157,860	£ 13,815,753	£ 26,388,088	1483	£ 2,446,113	£ 2,568,419	£ 4,905,681
Netham Lock	8	Netham Lock	FCERM 2065 & FCERM 2125	Low	100yr	715	£ 7,709,055	£ 8,094,507	£ 15,460,509	679	£ 1,069,107	£ 1,122,562	£ 2,144,094
Western Harbour	10	Bower Ashton	FCERM 2065 & FCERM 2125	Low	100yr	940	£ 2,712,534	£ 2,848,160	£ 5,439,986	920	£ 794,639	£ 834,371	£ 1,593,649
Eastern Corridor	13	Totterdown South Defences	FCERM 2065 & FCERM 2125	Low	100yr	0	£ -	£ -	£ -	440	£ 1,207,156	£ 1,267,514	£ 2,420,952
Feeder Road	14	Feeder Road	FCERM 2065 & FCERM 2125	Low	100yr	880	£ 4,599,620	£ 4,829,601	£ 9,224,538	880	£ 1,347,017	£ 1,414,368	£ 2,701,444
St. Annes	15	St. Anne's North Bank	FCERM 2065 & FCERM 2125	Low	100yr	1414	£ 10,843,116	£ 11,385,272	£ 21,745,869	0	£ -	£ -	£ -
St. Annes	16	St. Anne's South Bank	FCERM 2065 & FCERM 2125	Low	100yr	1010	£ 7,255,052	£ 7,617,804	£ 14,550,006	0	£ -	£ -	£ -
Detriment Mitigations	DM	Downstream, City Centre and Upstream of A417 Detriment	FCERM 2065 & FCERM 2125	Low	100yr	6119	£ 7,336,491	£ 7,703,316	£ 14,713,333	6729	£ 3,501,730	£ 3,676,817	£ 7,022,720
Total						15902	£ 119,889,520	£ 125,883,996	£ 235,495,758	13998	£ 15,494,400	£ 16,269,120	£ 30,885,654

Option 8C

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
1-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	200yr	N/A			200yr
1-2	Ramp	FCERM 2065		200yr	Floodgate	FCERM 2125		200yr
1-3	RC wall on minipiles	FCERM 2065	Low	200yr	N/A			200yr
1-4	Floodgate	FCERM 2065		200yr	N/A			200yr
1-5	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
1-6	[no work]			200yr	N/A			200yr
1-7	[no work]			200yr	N/A			200yr
1-8	Terraced Wall on minipiles	FCERM 2065	High	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-9	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
1-10	Ramp	FCERM 2065		200yr	Floodgate	FCERM 2125		200yr
1-11	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	200yr	N/A			200yr
1-12	1500d 19mL Contig Piled Wall	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
1-13	RC wall on minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
1-14	Use existing structure	FCERM 2065		200yr	N/A			200yr
1-15	Ramp	FCERM 2065		200yr	N/A			200yr
1-16	RC wall on minipiles	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-17	Ramp	FCERM 2065		200yr	N/A			200yr
1-18	RC wall on minipiles	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-19	Ramp	FCERM 2065		200yr	N/A			200yr
1-20	Floodgate	FCERM 2065		200yr	N/A			200yr
1-21	RC wall on minipiles	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-22	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
2-0	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
2-1	Choc. Path remedials - Wall on piles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
2-2	Choc. Path remedials - Wall on piles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
2-3	Choc. Path remedials - Wall on piles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
2-4	Choc. Path remedials - Wall on piles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
2-5	Wall raising	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
2-6	Choc. Path remedials - Wall on piles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
3-1	Floodgate	FCERM 2065		200yr	N/A			200yr
3-1	Reinforced Concrete wall (>1.2m)	FCERM 2065		200yr	Wall raising			200yr
3-2	Ramp	FCERM 2065		200yr	N/A			200yr
4-0	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-1	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
4-1a	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
4-2	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-2a	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-3	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-4	Ramp	FCERM 2065		200yr	N/A			200yr
4-5	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-6	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
5-0	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
5-1	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
5-2	Use existing structure	check		200yr	N/A			200yr
5-3	Floodwall on piles (3)	FCERM 2065	Low	200yr	Wall raising: Glazed	FCERM 2125		200yr
6-1	RC wall on minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
6-2	RC wall on minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
6-3	Use existing structure	FCERM 2065		200yr	N/A			200yr
7-1	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-2	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-3	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-4	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
7-5	Floodgate	FCERM 2065		200yr	N/A			200yr
7-6	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-7	Ramp	FCERM 2065		200yr	Floodgate	FCERM 2125		200yr
7-8	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-9	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-10	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-11	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-12	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-13	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-14	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-15	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-16	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-17	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-18	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-19	Use existing structure	check		200yr	N/A			200yr
7-20	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-21	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-22	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-23	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-24	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-25	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-26	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-27	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-28	RC wall on angled minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
7-29	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-30	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
7-31	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-32	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
7-33	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-34	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
7-35	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-36	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
8-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
8-2	Sheet Piled Wall (>100m length)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
8-2a	Sheet Piled Wall (<100m length)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
8-3	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
8-4	Ramp	FCERM 2065		200yr	N/A			200yr
8-5	[Removed from Scheme]	check		200yr	N/A			200yr
8-6	RC wall on minipiles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
8-7	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
8-8	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
8-9	[Removed from Scheme]	check		200yr	N/A			200yr
8-10	embankment	FCERM 2065		200yr	N/A			200yr
8-11	[lump sum item]	FCERM 2065		200yr	N/A			200yr
8-12	[lump sum item]	FCERM 2065		200yr	N/A			200yr
10-1a	1500d 23mL Contig Piled Wall	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
10-1b	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
10-1c	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
10-2	Use existing structure	check		200yr	N/A			200yr
10-3	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
10-4	Floodgate	FCERM 2065		200yr	N/A			200yr
10-4a	[Lump sum item]	FCERM 2065		200yr	N/A			200yr

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
10-5	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
13-1	[no work]			200yr	N/A			200yr
13-2	RC wall on minipiles	FCERM 2065	Low	200yr	N/A			200yr
13-3	N/A		Low	200yr	Wall raising	FCERM 2125	Low	200yr
14-1	Double Raked Piles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
14-2	[no work]	FCERM 2065		200yr	N/A	FCERM 2125		200yr
14-3	Double Raked Piles	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
15-1	Sheet Piled Wall (<100m length)	FCERM 2065	Low	200yr	N/A			200yr
15-2	Floodgate	FCERM 2065		200yr	N/A			200yr
15-3	Sheet Piled Wall (>100m length)	FCERM 2065	Low	200yr	N/A			200yr
15-4	Floodgate	FCERM 2065		200yr	N/A			200yr
15-5	Sheet Piled Wall (>100m length)	FCERM 2065	Low	200yr	N/A			200yr
16-1	Sheet Piled Wall (>100m length)	FCERM 2065	Low	200yr	N/A			200yr
16-2	[no work]		Low	200yr	Sheet Piled Wall (>100m)	FCERM 2125	Low	200yr
DM-1	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-2	Wall raising	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
DM-3	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-4	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-5	N/A			200yr	Embankment	FCERM 2125		200yr
DM-5b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
DM-6	Wall raising	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
DM-6b	Reinforced Concrete wall (<1.2m)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
DM-7	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-7b	Sheet Piled Wall (<100m length)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
DM-8	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-9	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM10	N/A			200yr	Wall raising	FCERM 2125		200yr
DM11	N/A			200yr	Embankment	FCERM 2125		200yr
DM12	Embankment	FCERM 2065		200yr	N/A			200yr
DM13	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
DM14	N/A	FCERM 2065		200yr	Wall raising	FCERM 2125		200yr
DM15	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
DM16	Reinforced Concrete wall (>1.2m)	FCERM 2065	Low	200yr	Wall raising	FCERM 2125		200yr
DM17	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr

Headline Arup Costs - Option 8C

Areas	Reaches	Reach Title	Protection Level	Placemaking	Return Period	CAPEX in 2024				Total CAPEX Cost in 2024				Total CAPEX Cost in 2065			
						Length of Defences built in 2024 (m)	CAPEX in 2024 (2019 equivalent)	+ service diversions	Optimism bias	Length of Defences built in 2024 (m)	CAPEX in 2024 (2019 equivalent)	+ service diversions	Optimism bias	Length of Defences built in 2065 (m)	CAPEX in 2065 (2019 equivalent)	+ service diversions	Optimism bias
Western Harbour	1	Entrance Lock / Western Harbour	FCERM 2065 & FCERM 2125	Low (except section 1-8)	200yr	1350	£ 14,799,676	£ 15,539,660	£ 29,680,751	909	£ 2,043,841	£ 2,146,033	£ 4,098,923				
Western Corridor	2	Cumberland Road	FCERM 2065 & FCERM 2125	Low	200yr	850	£ 34,095,177	£ 35,799,935	£ 63,437,485	850	£ 1,324,897	£ 1,391,142	£ 2,465,103				
Western Corridor	3	Cumberland Rd East Defence	FCERM 2065 & FCERM 2125	Low	200yr	16	£ 198,458	£ 208,381	£ 398,007	0	£ -	£ -	£ -				
Western Corridor	4	Commercial Road / Bathurst Dam	FCERM 2065 & FCERM 2125	Low	200yr	310	£ 5,749,125	£ 6,036,581	£ 11,529,871	288	£ 560,044	£ 588,046	£ 1,123,167				
Western Corridor	5	Clarence Road	FCERM 2065 & FCERM 2125	Low	200yr	570	£ 9,975,194	£ 10,473,954	£ 20,005,252	570	£ 736,423	£ 773,244	£ 1,476,895				
Eastern Corridor	6	Cattle Market Road	FCERM 2065 & FCERM 2125	Low	200yr	250	£ 1,874,659	£ 1,968,392	£ 3,759,629	250	£ 386,337	£ 405,654	£ 774,798				
Eastern Corridor	7	St. Philips Marsh / Totterdown Defences	FCERM 2065 & FCERM 2125	Low	200yr	1488	£ 13,634,642	£ 14,316,374	£ 27,344,275	1483	£ 2,677,367	£ 2,811,235	£ 5,369,459				
Netham Lock	8	Netham Lock	FCERM 2065 & FCERM 2125	Low	200yr	715	£ 7,754,411	£ 8,142,132	£ 15,551,472	679	£ 1,084,044	£ 1,138,246	£ 2,174,050				
Western Harbour	10	Bower Ashton	FCERM 2065 & FCERM 2125	Low	200yr	940	£ 2,817,824	£ 2,958,715	£ 5,651,145	920	£ 628,469	£ 659,892	£ 1,260,394				
Eastern Corridor	13	Totterdown South Defences	FCERM 2065 & FCERM 2125	Low	200yr	0	£ -	£ -	£ -	440	£ 1,218,449	£ 1,279,371	£ 2,443,599				
Feeder Road	14	Feeder Road	FCERM 2065 & FCERM 2125	Low	200yr	880	£ 4,653,094	£ 4,885,749	£ 9,331,780	880	£ 1,418,316	£ 1,489,232	£ 2,844,433				
St. Annes	15	St. Anne's North Bank	FCERM 2065 & FCERM 2125	Low	200yr	1414	£ 10,843,116	£ 11,385,272	£ 21,745,869	0	£ -	£ -	£ -				
St. Annes	16	St. Anne's South Bank	FCERM 2065 & FCERM 2125	Low	200yr	1010	£ 7,255,052	£ 7,617,804	£ 14,550,006	0	£ -	£ -	£ -				
Detriment Mitigations	DM	Downstream, City Centre and Upstream of A417 Detriment	FCERM 2125	Low	200yr	6319	£ 10,454,261	£ 10,976,974	£ 20,966,020	6729	£ 3,475,836	£ 3,649,628	£ 6,970,789				
Total						16112	£ 124,104,689	£ 130,309,923	£ 243,951,562	13998	£ 15,554,020	£ 16,331,721	£ 31,001,610				

Option 8C_B

Option 8C_B	2024				2065			
	Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking
1-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	high	200yr	N/A			200yr
1-2	Ramp	FCERM 2065		200yr	Floodgate	FCERM 2125		200yr
1-3	RC wall on minipiles	FCERM 2065	high	200yr	N/A			200yr
1-4	Floodgate	FCERM 2065		200yr	N/A			200yr
1-5	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
1-6	[no work]			200yr	N/A			200yr
1-7	[no work]			200yr	N/A			200yr
1-8	Terraced Wall on minipiles	FCERM 2065	High	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-9	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
1-10	Ramp	FCERM 2065		200yr	Floodgate	FCERM 2125		200yr
1-11	Reinforced Concrete wall (>1.2m)	FCERM 2065	high	200yr	N/A			200yr
1-12	1500d 19mL Contig Piled Wall	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
1-13	RC wall on minipiles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
1-14	Use existing structure			200yr	N/A			200yr
1-15	Ramp	FCERM 2065		200yr	N/A			200yr
1-16	RC wall on minipiles	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-17	Ramp	FCERM 2065		200yr	N/A			200yr
1-18	RC wall on minipiles	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-19	Ramp	FCERM 2065		200yr	N/A			200yr
1-20	Floodgate	FCERM 2065		200yr	N/A			200yr
1-21	RC wall on minipiles	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
1-22	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
2-0	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
2-1	Choc. Path remedials - Wall on piles	FCERM 2065		200yr	Wall raising	FCERM 2125		200yr
2-2	Choc. Path remedials - Wall on piles	FCERM 2065		200yr	Wall raising	FCERM 2125		200yr
2-3	Choc. Path remedials - Wall on piles	FCERM 2065		200yr	Wall raising	FCERM 2125		200yr
2-4	Choc. Path remedials - Wall on piles	FCERM 2065		200yr	Wall raising	FCERM 2125		200yr
2-5	Wall raising	FCERM 2065		200yr	Wall raising	FCERM 2125		200yr
2-6	Choc. Path remedials - Wall on piles	FCERM 2065		200yr	Wall raising	FCERM 2125		200yr
3-1	Floodgate	FCERM 2065		200yr	N/A			200yr
3-1	Reinforced Concrete wall (>1.2m)	FCERM 2065		200yr	Wall raising			200yr
3-2	Ramp	FCERM 2065		200yr	N/A			200yr
4-0	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-1	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
4-1a	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
4-2	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-2a	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-3	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-4	Ramp	FCERM 2065		200yr	N/A			200yr
4-5	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
4-6	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
5-0	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
5-1	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
5-2	Use existing structure			200yr	N/A			200yr
5-3	Floodwall on piles (3)	FCERM 2065	high	200yr	Wall raising: Glazed	FCERM 2125		200yr
6-1	RC wall on minipiles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
6-2	RC wall on minipiles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
6-3	Use existing structure			200yr	N/A			200yr
7-1	Ramp	FCERM 2065		200yr	Ramp	FCERM 2125		200yr
7-2	RC wall on angled minipiles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
7-3	RC wall on angled minipiles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
7-4	RC wall on angled minipiles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr

Option 8C_B	2024				2065				
	Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
7-5	Floodgate	FCERM 2065			200yr	N/A			200yr
7-6	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-7	Ramp	FCERM 2065			200yr	Floodgate	FCERM 2125		200yr
7-8	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-9	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-10	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-11	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-12	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-13	Ramp	FCERM 2065			200yr	Ramp	FCERM 2125		200yr
7-14	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-15	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-16	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-17	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-18	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-19	Use existing structure				200yr	N/A			200yr
7-20	Ramp	FCERM 2065			200yr	Ramp	FCERM 2125		200yr
7-21	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-22	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-23	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-24	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-25	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-26	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-27	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-28	RC wall on angled minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
7-29	Ramp	FCERM 2065			200yr	Ramp	FCERM 2125		200yr
7-30	Embankment	FCERM 2065			200yr	Embankment	FCERM 2125		200yr
7-31	Ramp	FCERM 2065			200yr	Ramp	FCERM 2125		200yr
7-32	Embankment	FCERM 2065			200yr	Embankment	FCERM 2125		200yr
7-33	Ramp	FCERM 2065			200yr	Ramp	FCERM 2125		200yr
7-34	Embankment	FCERM 2065			200yr	Embankment	FCERM 2125		200yr
7-35	Ramp	FCERM 2065			200yr	Ramp	FCERM 2125		200yr
7-36	Embankment	FCERM 2065			200yr	Embankment	FCERM 2125		200yr
8-1	Reinforced Concrete wall (>1.2m)	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
8-2	Sheet Piled Wall (>100m length)	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
8-2a	Sheet Piled Wall (<100m length)	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
8-3	Reinforced Concrete wall (<1.2m)	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
8-4	Ramp	FCERM 2065			200yr	N/A			200yr
8-5	[Removed from Scheme]				200yr	N/A			200yr
8-6	RC wall on minipiles	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
8-7	[Lump sum item]	FCERM 2065			200yr	N/A			200yr
8-8	Reinforced Concrete wall (>1.2m)	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
8-9	[Removed from Scheme]				200yr	N/A			200yr
8-10	embankment	FCERM 2065			200yr	N/A			200yr
8-11	[lump sum item]	FCERM 2065			200yr	N/A			200yr
8-12	[lump sum item]	FCERM 2065			200yr	N/A			200yr
10-1a	1500d 23mL Contig Piled Wall	FCERM 2065	high		200yr	Wall raising	FCERM 2125		200yr
10-1b	Embankment	FCERM 2065			200yr	Embankment	FCERM 2125		200yr
10-1c	[Lump sum item]	FCERM 2065			200yr	N/A			200yr
10-2	Use existing structure				200yr	N/A			200yr
10-3	Embankment	FCERM 2065			200yr	Embankment	FCERM 2125		200yr
10-4	Floodgate	FCERM 2065			200yr	N/A			200yr
10-4a	[Lump sum item]	FCERM 2065			200yr	N/A			200yr

Option 8C_B	2024				2065			
	Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking
10-5	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
13-1	[no work]			200yr	N/A			200yr
13-2	RC wall on minipiles	FCERM 2065	high	200yr	N/A			200yr
13-3	N/A		high	200yr	Wall raising	FCERM 2125	high	200yr
14-1	Double Raked Piles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
14-2	[no work]			200yr	N/A			200yr
14-3	Double Raked Piles	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
15-1	Sheet Piled Wall (<100m length)	FCERM 2065	high	200yr	N/A			200yr
15-2	Floodgate	FCERM 2065		200yr	N/A			200yr
15-3	Sheet Piled Wall (>100m length)	FCERM 2065	high	200yr	N/A			200yr
15-4	Floodgate	FCERM 2065		200yr	N/A			200yr
15-5	Sheet Piled Wall (>100m length)	FCERM 2065	high	200yr	N/A			200yr
16-1	Sheet Piled Wall (>100m length)	FCERM 2065	high	200yr	N/A			200yr
16-2	[no work]		high	200yr	Sheet Piled Wall (>100m	FCERM 2125	high	200yr
DM-1	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-2	Wall raising	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
DM-3	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-4	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-5	N/A			200yr	Embankment	FCERM 2125		200yr
DM-5b	Sheet Piled Wall (<100m length)	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
DM-6	Wall raising	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
DM-6b	Reinforced Concrete wall (<1.2m)	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
DM-7	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-7b	Sheet Piled Wall (<100m length)	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
DM-8	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM-9	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr
DM10	N/A			200yr	Wall raising	FCERM 2125		200yr
DM11	N/A			200yr	Embankment	FCERM 2125		200yr
DM12	Embankment	FCERM 2065		200yr	N/A			200yr
DM13	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
DM14	N/A			200yr	Wall raising	FCERM 2125		200yr
DM15	[Lump sum item]	FCERM 2065		200yr	N/A			200yr
DM16	Reinforced Concrete wall (>1.2m)	FCERM 2065	high	200yr	Wall raising	FCERM 2125		200yr
DM17	Embankment	FCERM 2065		200yr	Embankment	FCERM 2125		200yr

Headline Arup Costs - Option 8C_B

Areas	Reaches	Reach Title	Protection Level	Placemaking	Return Period	CAPEX in 2024				CAPEX in 2065			
						Length of Defences built in 2024 (m)	CAPEX in 2024 (2019 equivalent)	+ service diversions	Total CAPEX Cost in 2024 (2019 equivalent + other Costs and Fees + Optimism bias)	Length of Defences built in 2065 (m)	CAPEX in 2065 (2019 equivalent)	+ service diversions	Total CAPEX Cost in 2065 (2019 equivalent + other Costs & Fees + Optimism bias)
Western Harbour	1	Entrance Lock / Western Harbour	FCERM 2065 & FCERM 2125	High	200yr	1350	£ 15,128,476	£ 15,884,900	£ 30,340,159	909	£ 2,043,841	£ 2,146,033	£ 4,098,923
Western Corridor	2	Cumberland Road	FCERM 2065 & FCERM 2125	High	200yr	850	£ 34,095,177	£ 35,799,935	£ 63,437,485	850	£ 1,324,897	£ 1,391,142	£ 2,465,103
Western Corridor	3	Cumberland Rd East Defence	FCERM 2065 & FCERM 2125	High	200yr	16	£ 198,458	£ 208,381	£ 398,007	0	£ -	£ -	£ -
Western Corridor	4	Commercial Road / Bathurst Dam	FCERM 2065 & FCERM 2125	High	200yr	310	£ 5,887,365	£ 6,181,733	£ 11,807,111	288	£ 560,044	£ 588,046	£ 1,123,167
Western Corridor	5	Clarence Road	FCERM 2065 & FCERM 2125	High	200yr	570	£ 10,248,794	£ 10,761,234	£ 20,553,957	570	£ 736,423	£ 773,244	£ 1,476,895
Eastern Corridor	6	Cattle Market Road	FCERM 2065 & FCERM 2125	High	200yr	250	£ 1,994,659	£ 2,094,392	£ 4,000,289	250	£ 386,337	£ 405,654	£ 774,798
Eastern Corridor	7	St. Philips Marsh / Totterdown Defences	FCERM 2065 & FCERM 2125	High	200yr	1488	£ 14,259,122	£ 14,972,078	£ 28,596,670	1483	£ 2,677,367	£ 2,811,235	£ 5,369,459
Netham Lock	8	Netham Lock	FCERM 2065 & FCERM 2125	High	200yr	715	£ 8,080,331	£ 8,484,348	£ 16,205,104	679	£ 1,084,044	£ 1,138,246	£ 2,174,050
Western Harbour	10	Bower Ashton	FCERM 2065 & FCERM 2125	High	200yr	940	£ 2,916,224	£ 3,062,035	£ 5,848,486	920	£ 628,469	£ 659,892	£ 1,260,394
Eastern Corridor	13	Totterdown South Defences	FCERM 2065 & FCERM 2125	High	200yr	0	£ -	£ -	£ -	440	£ 1,429,649	£ 1,501,131	£ 2,867,160
Feeder Road	14	Feeder Road	FCERM 2065 & FCERM 2125	High	200yr	880	£ 5,075,494	£ 5,329,269	£ 10,178,903	880	£ 1,418,316	£ 1,489,232	£ 2,844,433
St. Annes	15	St. Anne's North Bank	FCERM 2065 & FCERM 2125	High	200yr	1414	£ 11,512,236	£ 12,087,848	£ 23,087,789	0	£ -	£ -	£ -
St. Annes	16	St. Anne's South Bank	FCERM 2065 & FCERM 2125	High	200yr	1010	£ 7,739,852	£ 8,126,844	£ 15,522,273	0	£ -	£ -	£ -
Detriment Mitigations	DM	Downstream, City Centre and Upstream of A417 Detriment	FCERM 2065 & FCERM 2125	High	200yr	6319	£ 10,907,861	£ 11,453,254	£ 21,875,715	6729	£ 3,475,836	£ 3,649,628	£ 6,970,789
Total						16112	£ 128,044,049	£ 134,446,251	£ 251,851,949	13998	£ 15,765,220	£ 16,553,481	£ 31,425,172

Option 9A

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
1-1	Reinforced Concrete wall (>1.2m)	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
1-2	Ramp	NPPF 2065		100/200 (no fbd)	Floodgate	NPPF 2125		100/200 (no fbd)
1-3	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
1-4	Floodgate	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-5	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-6	[no work]			100/200 (no fbd)	N/A			100/200 (no fbd)
1-7	[no work]			100/200 (no fbd)	N/A			100/200 (no fbd)
1-8	Terraced Wall on minipiles	NPPF 2065	High	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
1-9	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-10	Ramp	NPPF 2065		100/200 (no fbd)	Floodgate	NPPF 2125		100/200 (no fbd)
1-11	Reinforced Concrete wall (>1.2m)	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
1-12	1500d 19mL Contig Piled Wall	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
1-13	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
1-14	Use existing structure	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-15	Ramp	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-16	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
1-17	Ramp	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-18	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
1-19	Ramp	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-20	Floodgate	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
1-21	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
1-22	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
2-0	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
2-1	Choc. Path remedials - Wall on piles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
2-2	Choc. Path remedials - Wall on piles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
2-3	Choc. Path remedials - Wall on piles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
2-4	Choc. Path remedials - Wall on piles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
2-5	Wall raising	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
2-6	Choc. Path remedials - Wall on piles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
3-1	Floodgate	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
3-1	Reinforced Concrete wall (>1.2m)	NPPF 2065		100/200 (no fbd)	Wall raising			100/200 (no fbd)
3-2	Ramp	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
4-0	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
4-1	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
4-1a	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
4-2	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
4-2a	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
4-3	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
4-4	Ramp	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
4-5	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
4-6	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
5-0	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
5-1	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
5-2	Use existing structure	check		100/200 (no fbd)	N/A			100/200 (no fbd)
5-3	Floodwall on piles (3)	NPPF 2065	Low	100/200 (no fbd)	Wall raising: Glazed	NPPF 2125		100/200 (no fbd)
6-1	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
6-2	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
6-3	Use existing structure	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
7-1	Ramp	NPPF 2065		100/200 (no fbd)	Ramp	NPPF 2125		100/200 (no fbd)
7-2	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-3	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-4	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
7-5	Floodgate	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
7-6	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-7	Ramp	NPPF 2065		100/200 (no fbd)	Floodgate	NPPF 2125		100/200 (no fbd)
7-8	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-9	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-10	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-11	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-12	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-13	Ramp	NPPF 2065		100/200 (no fbd)	Ramp	NPPF 2125		100/200 (no fbd)
7-14	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-15	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-16	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-17	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-18	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-19	Use existing structure	check		100/200 (no fbd)	N/A			100/200 (no fbd)
7-20	Ramp	NPPF 2065		100/200 (no fbd)	Ramp	NPPF 2125		100/200 (no fbd)
7-21	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-22	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-23	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-24	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-25	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-26	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-27	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-28	RC wall on angled minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
7-29	Ramp	NPPF 2065		100/200 (no fbd)	Ramp	NPPF 2125		100/200 (no fbd)
7-30	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
7-31	Ramp	NPPF 2065		100/200 (no fbd)	Ramp	NPPF 2125		100/200 (no fbd)
7-32	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
7-33	Ramp	NPPF 2065		100/200 (no fbd)	Ramp	NPPF 2125		100/200 (no fbd)
7-34	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
7-35	Ramp	NPPF 2065		100/200 (no fbd)	Ramp	NPPF 2125		100/200 (no fbd)
7-36	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
8-1	Reinforced Concrete wall (>1.2m)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
8-2	Sheet Piled Wall (>100m length)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
8-2a	Sheet Piled Wall (<100m length)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
8-3	Reinforced Concrete wall (<1.2m)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
8-4	Ramp	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
8-5	[Removed from Scheme]	check		100/200 (no fbd)	N/A			100/200 (no fbd)
8-6	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
8-7	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
8-8	Reinforced Concrete wall (>1.2m)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
8-9	[Removed from Scheme]	check		100/200 (no fbd)	N/A			100/200 (no fbd)
8-10	embankment	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
8-11	[lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
8-12	[lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
10-1a	1500d 23mL Contig Piled Wall	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
10-1b	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
10-1c	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
10-2	Use existing structure	check		100/200 (no fbd)	N/A			100/200 (no fbd)
10-3	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
10-4	Floodgate	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
10-4a	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)

2024					2065			
Section	Main Solution	Protection Level	Placemaking	Return Period	Future Upgrades	Protection Level	Placemaking	Return Period
10-5	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
13-1	[no work]			100/200 (no fbd)	N/A			100/200 (no fbd)
13-2	RC wall on minipiles	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
13-3	N/A		Low	100/200 (no fbd)	Wall raising	NPPF 2125	Low	100/200 (no fbd)
14-1	Double Raked Piles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
14-2	[no work]	NPPF 2065		100/200 (no fbd)	N/A	NPPF 2125		100/200 (no fbd)
14-3	Double Raked Piles	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
15-1	Sheet Piled Wall (<100m length)	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
15-2	Floodgate	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
15-3	Sheet Piled Wall (>100m length)	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
15-4	Floodgate	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
15-5	Sheet Piled Wall (>100m length)	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
16-1	Sheet Piled Wall (>100m length)	NPPF 2065	Low	100/200 (no fbd)	N/A			100/200 (no fbd)
16-2	[no work]		Low	100/200 (no fbd)	Sheet Piled Wall (>100m)	NPPF 2125	Low	100/200 (no fbd)
DM-1	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM-2	Wall raising	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM-3	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM-4	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM-5	N/A			100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM-5b	Sheet Piled Wall (<100m length)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM-6	Wall raising	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM-6b	Reinforced Concrete wall (<1.2m)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM-7	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM-7b	Sheet Piled Wall (<100m length)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM-8	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM-9	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM10	N/A			100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM11	N/A			100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)
DM12	Embankment	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
DM13	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
DM14	N/A	NPPF 2065		100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM15	[Lump sum item]	NPPF 2065		100/200 (no fbd)	N/A			100/200 (no fbd)
DM16	Reinforced Concrete wall (>1.2m)	NPPF 2065	Low	100/200 (no fbd)	Wall raising	NPPF 2125		100/200 (no fbd)
DM17	Embankment	NPPF 2065		100/200 (no fbd)	Embankment	NPPF 2125		100/200 (no fbd)

Headline Arup Costs - Option 9A

Areas	Reaches	Reach Title	Protection Level	Placemaking	Return Period	CAPEX in 2024				CAPEX in 2065			
						Length of Defences built in 2024 (m)	CAPEX in 2024 (2019 equivalent)	+ service diversions)	Total CAPEX Cost in 2024 (2019 equivalent + other Costs and Fees + Optimism bias)	Length of Defences built in 2065 (m)	CAPEX in 2065 (2019 equivalent)	+ service diversions)	Total CAPEX Cost in 2065 (2019 equivalent + other Costs & Fees + Optimism bias)
Western Harbour	1	Entrance Lock / Western Harbour	NPPF 2065 & NPPF 2125	Low (except section 1-8)	100/200yr no fbd	1350	£ 14,754,893	£ 15,492,638	£ 29,590,939	909	£ 2,436,521	£ 2,558,347	£ 4,886,442
Western Corridor	2	Cumberland Road	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	850	£ 34,110,939	£ 35,816,486	£ 63,466,813	850	£ 1,343,596	£ 1,410,775	£ 2,499,894
Western Corridor	3	Cumberland Rd East Defence	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	16	£ 190,743	£ 200,281	£ 382,536	0	£ -	£ -	£ -
Western Corridor	4	Commercial Road / Bathhurst Dam	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	310	£ 5,730,466	£ 6,016,989	£ 11,492,449	288	£ 715,312	£ 751,078	£ 1,434,559
Western Corridor	5	Clarence Road	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	560	£ 9,768,138	£ 10,256,545	£ 19,590,001	570	£ 1,188,718	£ 1,248,153	£ 2,383,973
Eastern Corridor	6	Cattle Market Road	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	250	£ 1,848,605	£ 1,941,035	£ 3,707,377	250	£ 382,670	£ 401,804	£ 767,446
Eastern Corridor	7	St. Philips Marsh / Totterdown Defences	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	1488	£ 13,329,301	£ 13,995,766	£ 26,731,913	1483	£ 2,735,423	£ 2,872,194	£ 5,485,890
Netham Lock	8	Netham Lock	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	715	£ 7,728,503	£ 8,114,928	£ 15,499,512	679	£ 1,098,981	£ 1,153,930	£ 2,204,006
Western Harbour	10	Bower Ashton	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	940	£ 2,791,241	£ 2,930,803	£ 5,597,834	920	£ 800,972	£ 841,021	£ 1,606,350
Eastern Corridor	13	Totterdown South Defences	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	0	£ -	£ -	£ -	440	£ 1,216,835	£ 1,277,677	£ 2,440,363
Feeder Road	14	Feeder Road	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	880	£ 4,635,269	£ 4,867,033	£ 9,296,033	880	£ 1,391,579	£ 1,461,158	£ 2,790,812
St. Annes	15	St. Anne's North Bank	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	1414	£ 10,843,116	£ 11,385,272	£ 21,745,869	0	£ -	£ -	£ -
St. Annes	16	St. Anne's South Bank	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	1010	£ 7,255,052	£ 7,617,804	£ 14,550,006	110	£ 790,154	£ 829,662	£ 1,584,654
Detriment Mitigations	DM	Downstream, City Centre and Upstream of A417 Detriment	NPPF 2065 & NPPF 2125	Low	100/200yr no fbd	5379	£ 7,208,156	£ 7,568,564	£ 14,455,957	6609	£ 3,815,226	£ 4,005,987	£ 7,651,435
Total						15162	£ 120,194,423	£ 126,204,144	£ 236,107,239	13988	£ 17,915,987	£ 18,811,786	£ 35,735,824

Appendix E – Asset Inspection Data Review

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Project title	Bristol Flood Strategy	Job number	260498
cc	Arup Strategy team	File reference	BAFMS_FN01_BCC Asset Inspection Data Review
Prepared by	Ethan Perry (Bristol)	Date	31 January 2020
Subject	Review of BCC Asset Inspection Data in relation to proposed defences		

1 Introduction

1.1 Purpose

The purpose of this document is to review the information provided by Bristol City Council (BCC) to Arup on their asset condition surveys along the River Avon, and assess its relevance to the Bristol Flood Strategy project. The analysis focuses on the assets identified as being in a serious or critical condition.

1.2 Information analysed

The information analysed was sent by BCC on 09/01/2020 (email from Matt Sugden), consisting of very brief commentary on the asset conditions and photographic evidence in pdf format. A list of the assets reviewed is in Appendix A.

1.3 Approach

The work presented here is a high-level cross-check of the assets classified as *being in a serious or critical condition* against the locations and proposals for raised defences in Bristol (as defined at the time of writing this note).

2 Asset review

Inspection data included locations and tag numbers of the assets, images and a brief description of their condition. The assets will be referred to by tags given in the condition survey in this report.

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2.1 NCN03a

2.1.1 Description

NCN03a (bridge supporting chocolate path railway next to Underfall Yard) is a severely corroded metal bridge with significant weaknesses along the main girder at the bearing and stiffener locations, shown in Figure 1: Images of NCN03A (taken from the information provided by BCC).



A full structural survey has been recommended as part of the condition survey before the bridge is confirmed suitable for vehicles. The bridge supports a section of the Chocolate path, adjacent to Cumberland Road and just upstream of Ashton Avenue Bridge, as per Figure 2. The purpose of the bridge, and why it is in place instead of the construction type of the rest of the wall, is unknown. It may have been put in place after a partial wall collapse.



Figure 1: Images of NCN03A (taken from the information provided by BCC).

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Figure 2: Location of asset NCNO3a.

2.1.2 Effect on Bristol Flood Strategy

The flood strategy shows flood walls being constructed along Cumberland Road (reach 2), including additional placemaking on the river side of the wall. As this bridge is directly supporting a section of the Chocolate Path, works in this area could not be completed until the bridge has been structurally assessed and suitably repaired or replaced.

2.2 NCS 41

NCS 41 (flood defence wall on south bank of New Cut) is a concrete wall that has deformed blockwork on top of a capping beam. This is causing cracking in the blockwork at the end of these sections, shown in Figure 3. The wall forms part of a flood defence on the South bank of the New Cut, adjacent to the Paintworks development, as per Figure 4: Location of asset NCS41



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Figure 3: Images of flood wall asset NCS41(taken from the information provided by BCC).



Figure 4: Location of asset NCS41

2.2.1 Effect on Bristol Flood Strategy

The existing wall is likely to be utilised as part of the strategy, and it may require raising in the 2060s to account for sea level rise. An assessment and suitable repairs to the wall are therefore required to ensure they operate effectively.

2.3 NCN 02

NCN 02 (vegetated wall on downstream end of Spike Island) is a heavily vegetated wall that has partially collapsed, shown in Figure 5. The wall is at the downstream end of Spike Island, adjacent to the slipway down from Brunel Way, shown in Figure 6.

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Figure 5: Image of asset NCN02 (taken from the information provided by BCC).



Figure 6: Location of asset NCN02

2.3.1 Effect on Bristol Flood Strategy

In this area, it is likely that the raised road itself will provide the defence height, and therefore the wall at NCN 02 will not affect the works. If new defences were to be constructed on this alignment, it is likely that the existing wall would not be relied upon for support.

2.4 NCN 20

NCN 20 (timber retaining wall just upstream of Bathurst Basin) is a timber retaining wall that has collapsed or deformed in sections, causing it to lean into the river, shown in Figure 7. The wall is just upstream of Bathurst Basin, on the North bank of the New Cut, shown in Figure 8.

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Figure 7: Image of NCN 20 (taken from the information provided by BCC).



Figure 8: Location of NCN 20

2.4.1 Effect on Bristol Flood Strategy

The raised wall proposed along this area is likely to be a reinforced concrete flood wall. It is likely that the detailed design of this will not consider any support provided by the timber retaining wall, and therefore the condition of this asset will have little effect on the strategy.

2.5 NCS 02 and NCS 04

Both NCS 02 and NCS 04 (failed timber structures adjacent to Ashton Avenue Bridge) are timber structure adjacent to Ashton Avenue Bridge that have collapsed into the river, shown in Figure 9, Figure 10 and Figure 11 respectively. Although defences are proposed in these areas, these structures are not anticipated to affect their design.

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Figure 9: Image of NCS 02 (taken from the information provided by BCC).



Figure 10: Image of NCS 04 (taken from the information provided by BCC).

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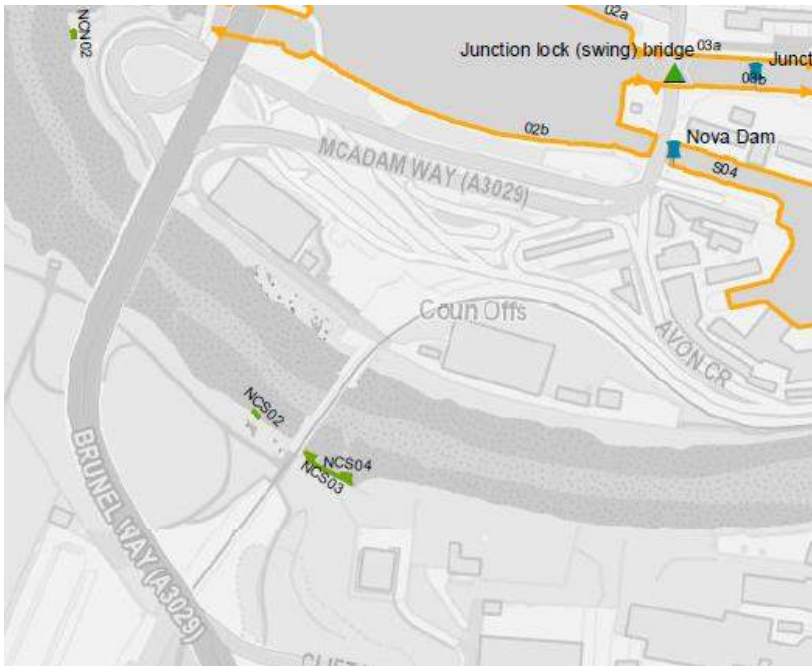


Figure 11: Location of NCS 02 and NCS 04

3 Summary

Assets NCN03a and NCS 41 are likely to have a significant interference with the proposed defences anticipated near them. They will require surveying and suitable repairs or replacement prior to construction of the defences proposed by the Strategy. These have been added to the project risk register.

The other assets listed above are in areas where defences are planned but are not thought likely to significantly affect detailed design.

Comprehensive site investigations and further inspection of assets will be required for all the works proposed by the Strategy during the detailed design stage.

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Appendix A

Asset/Aspect Damaged	Tag	Is it within a defence area?	Location	Information
Wall	N25	No	Just D/S of Marsh Bridge	30m wall leaning approx. 4.5 degrees over water.
Arch	NCS33	No	Temple Island, U/S end of meander, North bank.	Backwall of masonry arch failure.
Bridge	NCN03 a	Yes	Cumberland Rd, Just U/S of Ashton Avenue Bridge	Corrosion of metal bridge, replacement or full structural survey recommended
Capping Beam	NCN42	No	Just D/S of Sparke Evans Park opposite side	Low cover on capping beam with exposed reinforcement
Retaining Wall	N11	No	Peros Bridge, Bordeaux Quay	Indentations
Wall	N13	No	Peros Bridge	Bulging underwater
Wall	N14	No	Peros Bridge	3m ² hole in wall, potentially a feature of culvert
Masonry Wall	N28	No	U/S of Marsh Bridge, opposite side of river to Brandon Hire Station	Area of scour 6m wide and 0.3m deep.
Concrete Wall	NCS 36	No	Just U/S junction between Bath Rd and Wells Rd, that side of river.	Cracked buttresses and face.
Collapsed Masonry Asset	NCS35 B	No	At junction between Bath Rd and Wells Rd, South bank.	Collapsed Masonry Asset
Masonry Wall	NCN18	No	Gods Garden	Settlement at base of wall, failure in area that may result in failure of the above structure due to lack of support.
Feeder Canal	N27	No	U/S of Marsh Bridge, approx. in line with Arthur Street	Deformed section, collapsed masonry section, scour at eastern end
Trench Sheets	N34	No	U/S of Barton Hill Bridge, North bank of river	Collapsed, missing and deformed trench sheets
Wall	NCS23	No	Just D/S of Bedminster Bridge	Cracked and deformed wall leaning toward the river

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			Roundabout, South Bank	
Capping Beam	NCS 41	Yes	D/S end of Central Trading Estate	Deformed blockwork on top of capping beam
Masonry Wall	S09	No	U/S of Albion Dockyard	Collapsed section of wall
Masonry Wall	N32A	No	D/S of Barton Hill Bridge	Collapsed deformed sections along its length
Masonry Wall	NCN19	No	U/S of Bath Hurst Basin, along River Avon, North bank	Deformation and cracks on masonry wall with timber elements and coping stones on top.
Masonry Wall	NCN 16	No	D/S of Bath Hurst Basin, along River Avon, North bank	Cracked wall and section fallen away.
Timber Wall	NCN 20	Yes	U/S of Bathurst Basin, along River Avon, North bank	Timber retaining wall, collapsed in section leaning into river in other.
Masonry Wall	NCS 18	No	D/S of Bath Hurst Basin, along River Avon, South bank	Section of Masonry wall lost, deformation in areas
Masonry Wall	NCS 20	No	U/S of Bath Hurst Basin, along River Avon, South bank	Top of wall lost in section.
Masonry Wall	NCS 22	No	U/S of Bath Hurst Basin, along River Avon, South bank	Failed in multiple locations
Masonry Wall	NCS 21	No	U/S of Bath Hurst Basin, along River Avon, South bank	Large deformation and crack
Masonry Wall	NCS 27	No	Just U/S of Bedminster Bridge Roundabout, South bank	Upper portion of wall appears to have collapsed
Masonry Wall	NCS 28	No	Close to Langton Street Bridge	Large area of deformation
Sheet Piles	NCN 35a	No	Just D/S of Netham Lock, North bank	Water has eroded the bank, may reduce capacity of sheet piles.
Sheet Piles	NCN36	No	Just D/S of Netham Lock, North bank	Water has eroded the bank, may reduce capacity of sheet piles.
Wall	NCN02	Yes	Just D/S of Brunel way crossing the River Avon Southern channel	Heavily vegetated wall, partial collapse.
Masonry Wall	NCN11	No	D/S of Bath Hurst Basin, along River Avon, North bank	Multiple holes within the wall



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Masonry Wall	NCN13	No	D/S of Bath Hurst Basin, along River Avon, North bank	Section missing at base of retaining wall
Timber Pier	NCS 02	Yes	Just D/S of Ashton Ave Bridge	Failure
Timber Retaining wall	NCS 04	Yes	Just U/S of Ashton Avenue Bridge	Partial loss of horizontal retaining planks.
Masonry Wall	NCS 06	No	D/S of Ashton Ave Bridge	Holes within masonry wall
Masonry Wall	NCS 07	No	D/S of Ashton Ave Bridge	Holes within masonry wall
Masonry Wall	NCS 08	No	D/S of Ashton Ave Bridge	Holes within masonry wall
Masonry Wall	NCS 10	No	D/S of Ashton Ave Bridge	Holes and partial collapse
Masonry Wall	NCS 13	No	D/S of Ashton Ave Bridge	Holes and partial collapse
Masonry Wall	NCS 18	No	U/S of Bath Hurst Basin, along River Avon, South bank	Holes within masonry wall
Masonry Wall	N33	No	D/S of Barton Hill Bridge, North bank of river	Collapsed sections and areas of major deformation
Timber Structure	N30	No	Just D/S of where St Philips Causeway Crosses the northern river channel	Sections where no retaining wall, other sections in advanced state of deterioration
Masonry Wall	N27A	No	U/S of Marsh Bridge	Major crack across 4m length
Wall	N27C	No	U/S of March Bridge	Deformed timber elements above and below water

DOCUMENT CHECKING (not mandatory for File Note)

	Prepared by	Checked by	Approved by
Name	Ethan Perry (Bristol)	Phil Smith / M. Piedra	Henrietta Ridgeon
Signature			

Appendix F – Structures Review Note

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Project title	Bristol Tidal Flood Risk Management Scheme	Job number	260498-00
cc	Robin Campbell Matt Sugden	File reference	4-08-Structures
Prepared by	Nick Jones	Date	25 April 2018
Subject	High level review of AECOM structural proposals for significant assumptions or opportunities that may impact on defence structures strategy overall viability		

1 Introduction

Arup have been engaged by Bristol City Council (BCC) to refine the strategy for the city's tidal flood risk management (FRM) structures along the River Avon through Bristol. This strategy refinement builds upon prior work by AECOM most recently and other consultants before AECOM. The AECOM strategy Option D (low, low, high) is the preferred option [Table 1 and Section 8 in AECOM's Preferred Option Selection Report], which is to: build low defences in AECOM-termed epoch 1 (2015-2030); maintain these low defences and build additional low defences in the medium term (epoch 2, 2030-2065); replace / significantly extend / include new reaches to create high defences in epoch 3 (2065 onwards) [refined defence phasing from Section 0.3 of AECOM's Preferred Option Development Report].

The strategy refinement seeks to link the aspirations for the FRM structures with wider aspirations for public realm enhancement, sustainable and low-energy transport, fluvial flood risk management, and unlocking development potential along the River Avon between Netham and the Cumberland Basin.

This note presents the output of a high-level review of the engineering proposals provided by AECOM for the FRM structures, to uncover aspects of the proposals that may be less well developed, or that are based on significant assumptions that may have a significant impact on the viability of the strategy. The note highlights potential opportunities to address these aspects and seeks to prioritise the reaches where the greatest benefit can be gained from further design development.

Two companies have previously separately reviewed the AECOM proposals: Arcadis reviewed the cost build-up delivered as part of AECOM's scope. Balfour Beatty (BB) reviewed construction methods, initial costings against the AECOM build-up, and suggested potential delivery mechanisms. This note builds upon these previous studies.

In addition to the AECOM, BB and Arcadis studies that were provided at the start of Arup's commission, BCC recently provided access to the preliminary report by C2HM on the deformation of the chocolate path retaining wall at Cumberland Road.

Technical Note

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BCC are carrying out a parallel project, Bristol harbour walls condition survey, which in due course could inform this strategy. Outputs were not available at the time of preparing this note.

2 Documents reviewed

Of the documents listed, only certain sections were reviewed. These are outlined following each document reference.

- River Avon Tidal Flood Risk Management Strategy, Preferred option report, April 2017, issue 4; AECOM; (2017-04-16 Preferred Option Selection Report Iss4.pdf), selected sections only where relevant to option D. Referred to hereafter as the “Preferred Option Selection Report”
- River Avon Tidal Flood Risk Management Strategy, Preferred Option Development Report; November 2017, issue 4; AECOM; (301117 Pref Opt Devpt in out design phase rept_BT_BathurstUpdates_JRD_integrated_Iss4.pdf)– selected sections only
- River Avon Tidal Flood Risk Management Strategy, Outline Design Briefing Report; December 2017, issue 4; AECOM; (2017-12-06 Avon Outline Design Report Final_JRD_Iss4_integrated.pdf) – selected sections only, referred to hereafter as the “Outline Design Report”
- Appendix E of the above Outline Design Report; (App E_Costing table_Bathurst_update.xls)
- Bristol Tidal Flood Risk Management Strategy, SCAPE procedure Interim Feasibility Report; Balfour Beatty; January 2018 (Defence Interim Feasibility Report Rev1 16.01.18 full.pdf) – relevant technical sections only
- Arcadis Cost Overview of the Avon Tidal Flood Risk Management Strategy; April 2017; Arcadis; (2017-04-18 Arcadis Cost Review Avon Strategy - April 2017_complete.pdf)
- Chocolate Path River Wall Stability –Preliminary Assessment of Deformation; January 2018, CH2M; (180116 CPRW Prelim Assessment Report DRAFT v0.pdf)

3 Limitations and notes

The review focus is on technical implications and apparent omissions. This review has not had input from quantity surveyors. Cost build-ups have not been reviewed, only the stated values as compared against stated section totals and BB rates. Engineering assessments of the methods proposed (e.g. reviews of the size and depth of piles proposed or dimensions of RC walls) have not been carried out. We were asked at this stage not to review or propose alternative alignments since the AECOM deliverables were explicitly at strategic level and the Arup appointment does not seek to step beyond the strategic level.

The review has not considered “non-flood wall” aspects such as public realm enhancements or Greenway proposals.

In this note, the phasing relates to the phases outlined in the AECOM Outline Design Report Appendix E: “low defence” (2015-2030) and “high defence” (2065 onwards) only.

Technical Note

260498-00

25 April 2018

4 Summary of Conclusions

Generally, given the high-level nature of the engineering proposals, the variety of existing conditions encountered and the paucity of information regarding the condition of the existing structures along the reaches considered, the AECOM proposals seem sensible from both a technical and cost-conservatism viewpoint for the strategy-level of the project.

There are opportunities to refine the engineering, and there are numerous aspects that are subject to residual cost uncertainty. These are summarised in Table 1 that follows, and expanded upon in Section 7 onwards.

We feel there are significant cost impacts associated with the contiguous-piled wall reaches that have not been adequately addressed and that may not be adequately covered by the optimism bias allowance, and that these reaches in particular would benefit from further input from experienced contractors to flush out the implications of decisions that need to be made here.

It is worth noting that there is not a single “big-ticket” reach that will bring great savings, and also that the contiguous piled wall proposals are unlikely to be addressed with a “one-size-fits-all” solution. Serious effort will be required to address the remaining significant cost uncertainties on these reaches, and this would be most appropriately addressed at a more detailed level of design combined with refinement of the defence alignments.

Table 1: Summary of significant assumptions or risks on a reach-by-reach basis

Reach	Cumulative "built-up" reach spend at Epoch 3 (refer to note below) as % of total strategy cost (total strategy cost including lump sums and optimism bias)	AECOM proposal main cost component	Epoch in which significant component occurs	AECOM main cost component cost (£M)	AECOM main cost component stated rate per metre (£k/m)	AECOM main cost component % of reach "built-up" spend in relevant epoch	Epoch 1 "built-up" reach spend (2015) (£M)	Epoch 2 (2030 - 2065) "built-up" reach spend (£M)	Epoch 3 (2065 on) "built-up" reach spend (£M)	Cumulative "built-up" reach spend by Epoch 3 (£M)	BB / ARCADIS / AECOM cost comments	Arup assessment of potential variation
Entrance Lock	11%	New lock gate	Epoch 1	5	227	57%	8.8	0.0	3.0	11.8	Reasonable: gate allowances tested	Medium risk of cost increase due to potential for high-spec public realm works
Cumberland Road	6%	Contiguous piled walls between chocolate path retaining wall and Cumberland Road retaining wall	Epoch 3	5	7.88	98%	0.0	1.4	5.1	6.5	Cost uncertainty depending on how contiguous piling is carried out, all rates higher than AECOM assumption	High risk of cost increases due to methods required for contiguous piled walls (river working or full road closure). Investigate alternative solutions e.g. repair/rebuild of existing chocolate path wall plus new flood wall to top. May simply shift cost within BCC to other schemes. Risk of cost increases due to interaction with heritage railway. PRIORITY ACTION TO INVESTIGATE THIS REACH
Cumberland Road East	0.4%	Ramp	Epoch 2	0.2	60.0	60%	0.0	0.3	0.1	0.4	Reasonable	Insignificant , although interactions with heritage railway may push costs up. Cost/m looks high because the ramp at ~£180k addresses 3 metres defence length
Commercial Road and Bathurst Dam	2%	Contiguous piled walls "river side" of existing retaining walls	Epoch 2	1	5.01	63%	0.0	1.6	0.5	2.1	Method-based cost uncertainty as Cumberland Road. Dam high-phase cost risk	High risk of cost increase, albeit medium impact on total strategy cost. Investigate alternative solutions but for limited gain. May simply shift cost within BCC to other schemes
Clarence Road	4%	Contiguous piled walls "river side" of existing retaining walls	Epoch 2	3	5.01	100%	0.0	3.0	0.9	3.9	Method-based cost uncertainty as Cumberland Road.	High risk of cost increases due to methods required for contiguous piled walls (river working or full road closure). Investigate alternative solutions e.g. repair/rebuild of existing riparian wall plus new flood wall to top. May simply shift cost within BCC to other schemes. PRIORITY ACTION TO INVESTIGATE THIS REACH
Cattle Market Road	1%	RC fin walls on piled foundation	Epoch 2	0.9	4.3	96%	0.0	0.9	0.2	1.1	not reviewed	Costs not tested but variations are still minor to overall strategy cost. Potential for cost and timescale increase due to interaction with Network Rail. Potential to reduce costs by investigating omission of piled foundations
Totterdown and St. Phillips	8%	RC fin walls, sheet piled walls	Both 1 and 3	6	3.56	73%	3.5	0.0	4.7	8.2	Reasonable	Medium risk due to variability of proposals and interactions with many land parcels. Opportunity to reduce cost by taking development land for FRM solution. Cost/m for sheet piles reported. Cost/m for RC walls is reported at £1.91k/m
Netham (low defences in Epoch 1)		New lock gate	Epoch 1	5	250	76%	6.6	0.0	0.0		Reasonable	Minor risk. No action required
Netham (high defences in Epoch 3)	10%	Contiguous piled walls "river side" of existing retaining walls	Epoch 3	4	8.45	93%	0.0	0.0	4.3	10.9	Method-based cost uncertainty due to river-based contiguous piles	High risk of cost increase. Investigate alternative measures which may reduce cost. PRIORITY ACTION TO INVESTIGATE THIS REACH
Detriment Mitigation	3%	RC walls	Epoch 3	0.4	1.91	40%	2.6	0.0	1.0	3.6	not reviewed	Medium risk. Rates allow for RC walls which are tested.

Total "costed" costs	46%						21.5	7.2	19.8	48.5		
Lump sum allowances (£M)	24%						Epoch 1 and 2 are presented together by AECOM as "low defences"		13.7	11.4	25.1	
Optimism bias allowances	31%						Epoch 1 and 2 are presented together by AECOM as "low defences"		19.3	13.2	32.5	
Total strategy costs	100%							62	44	106		

* "built-up" reach costs means those costs that have been built up by AECOM, based on the engineering proposals. These are presented by AECOM on a reach by reach basis. There are then additional allowances called "construction lump sums" which have been applied to the total ""built-up" strategy cost for epochs 1+2 and epoch 3. These cover services, existing outfalls, drainage and landscape /public realm. Added to this subtotal is then a 60% optimism bias based on the subtotal. Then additional lump sums are applied as a percentage to the subtotal (excluding the optimism bias) to cover other aspects such as environmental mitigation, ground investigation and surveys, professional services (design, PM, supervision etc.), compenstaion and compulsory purchase.

5 General comments

AECOM's assumptions on the usefulness or otherwise of existing structures (Table 6 of the Preferred Options Development Report) appear reasonable for strategy development and we note this approach was agreed with BCC. Given the multiple instances of retaining wall failure or deep-seated land slips that have occurred on the northern bank of the New Cut since the 1980s (summarised in Table 5-1 of the CH2M report), the proposal of new-build retaining structures seems reasonable as an initial solution.

AECOM's rationale behind generally adopting a frontline defence alignment, and hence construction methods appropriate to this, appear sensible for the current stage of the strategy, as these generally impose a more conservative choice of solution which is likely to be at the higher end of the ranges of cost.

The rationale generally seeks to decouple the flood walls from the existing riparian retaining walls by replacing the function of the existing retaining walls for land on the dry-side with new "full-height" retaining walls. This provides long-term structural reliability on the land side in the form of new retaining walls, and the freedom for BCC to address repairs to the existing riparian retaining walls at a reduced degree of urgency (and possibly reduced severity of intervention as the existing walls become broadly cosmetic), while retaining the heritage river frontage where possible. The new contiguous piled walls provide an opportunity to tie the existing riparian walls back into a new engineered structure and enhance their stability. The new contiguous piled walls will protect the existing riparian walls from loads "land-side" of the new walls, which may enhance their stability safety factors without tying back. However, the impact on the heritage walls during construction does not appear to have been considered (beyond adopting contiguous piled walls as a likely lowest-impact measure) and this would need investigation.

The new structures are large, requiring substantial engineered solutions, and the presence of existing heritage walls imposes constraints on the construction methods that can be adopted. The buildability requirements that spring from the construction methods in turn impose constraints on the alignments (e.g. far enough away from existing walls to allow **piling from the land-side – which effectively implies total road closures of significant Bristol streets for the duration of construction**, or close enough to the river channel to allow **piling from the river – which would entail very significant costs, programme implications and environmental disruption**). There are potential opportunities to reduce this cost that should be investigated– refer to Section 6 that follows.

The rationale behind the choice of contiguous piled walls over other methods of piling (where contiguous piles have been proposed) is explained. Contiguous piles are bored rather than driven which reduces the effects on existing masonry walls. They are able to be bored into the bedrock unlike driven piles (necessary for wall stability in the current proposals), and they can provide long design life without the need for the significant sacrificial thickness allowance of a sheet pile.

Where sheet piles are proposed, both AECOM and Balfour Beatty have assumed conventional sheet piling operations in the costings. There are opportunities to be gained from refining the piling method used, e.g. "silent piling" methods (refer to Section 6).

BB have raised concerns about the cost-effective buildability of various reaches as currently proposed, *both sheet piled and contiguous piled*, due to the potential for long-duration road-closures and significant temporary works if piled from the land side of the riparian walls, or the potential for

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in-river working. BB have questioned the feasibility of piling from a barge-mounted rig due to the bank profile. They propose significant temporary works in the river to support a piling rig if access cannot be obtained from the land side. This is a significant source of cost-uncertainty in addition to the omission of other river-side cost uncertainties, and this will need to be addressed as the engineering proposal is refined.

AECOM state there is an opportunity to revisit the chosen alignments and construction methods (which may reduce costs) in the Outline Design Report. This is addressed further in Section 6 of this note.

AECOM have allowed an optimism bias of 60% of the sum of costed elements and construction-related lump sums to account for the low level of design certainty at this stage. This is not 60% of the total projected strategy cost, but approximately 30% of the projected total. Given the range of costs suggested for the contiguous piled reaches in particular, and acknowledging that these costs probably do not account for the full impacts of river-based working or road stoppage, **we feel that the optimism bias allowance may be insufficient to absorb the potential cost increases on this strategy.** Arcadis addressed this aspect from a different angle (Section 8 of the Arcadis cost overview) and stated “It is noted that under Environment Agency best practice the 95th percentile risk should not exceed the 60% Optimism Bias, this indicates there may not be sufficient allowance and the project may be assessed as having a too larger risk to progress in it’s current format” [sic].

AECOM have allowed a multiplier on the costed elements to account for other scheme-wide aspects such as landscaping and public realm, drainage, etc. Arcadis suggest that several of these allowances may be insufficient.

6 Opportunities

Review the reasoning behind new “frontline defences” being pushed into the river channel (e.g. at Clarence Road) during detail design – this forces expensive construction measures, although alternatives may mean more disruption to existing roads, landowners etc.

Incorporate findings from the forthcoming outputs of the harbour condition survey when these are shared and review the statements made in this technical note.

Investigate capacity of existing river-front walls, to assess whether they can be strengthened sufficiently for piling rigs to be placed behind them (possibly using ground anchors or significant temporary blockstone or rock fill against the river face?) to accommodate the AECOM proposal, or to place new FRM walls on top of existing post-repair, e.g. at Cumberland Road and Clarence Road (this latter option would then mean the FRM structures rely on ongoing maintenance of the riparian walls). This opportunity is signposted by AECOM in the preferred option selection report. The C2HM report provides considerable information on possible options which could be applicable (albeit it does not consider piling rig loads) and gives a qualitative indication of the relative costs of the options. Strengthening/repair of the existing walls is cited by CH2M as having been carried out for BCC at Clarence Road.

A method that was not discussed by CH2M is a section-by-section new-build to the current surface profile in reinforced concrete using textured formwork to provide a “stone appearance” finished surface that would approximate to that of the existing historic walls (e.g. using Hoss formwork

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liners). A rebuild of this nature would however require significant temporary works (which C2HM state are likely for any re-build options).

Significant work would be required to justify the existing riparian walls for the required lifetime of the FRM structures, both in terms of investigation and analysis, and also in terms of reconstruction or strengthening.

Review whether ground anchors could be used in conjunction with a different solution to reduce construction effort of contiguous piled walls. This is unlikely to be suitable for the current alignment at Cumberland Road due to the proposed piles being behind the existing river walls, but potentially useful for “frontline defences” at Clarence Road, Commercial Road and Netham. Early Contractor Involvement should be useful to generate options with due regard for the site conditions.

Similarly, at sheet piled wall locations, could ground anchors be incorporated into the proposals to reduce pile length, particularly if a development opportunity simplifies obtaining permission to install anchors?

Investigate CFA piling feasibility for Clarence Road during detailed design.

“Silent piling” such as offered by Giken may reduce plant requirement and vibration impact due to sheet pile works where sheet piles are proposed. In this method, the rig crawls along the already-installed sheet piled length to reach the worksite and uses the installed sheet piles themselves to react against when driving the new pile section. In this way it may significantly reduce the plant and temporary works/access requirements.

Investigate the “King sheet pile” option proposed by BB for sheet piled reaches: this may have additional merit in minimising the impact on existing outfalls and through-defence drainage.

Revisit reasoning for piled foundations to otherwise-surface-founded RC fin walls: a more generous settlement allowance may allow piles to be omitted.

Provide a “soft” defence to the river side of Totterdown and St Philips as redevelopment permits: a grassed embankment with path to the crest will take land out of the developable area but will be more sympathetic to the river landscape.

There is an opportunity to investigate whether the utilities would appreciate, and be prepared to contribute to, a “protected” services corridor behind the new FRM structures, perhaps integrated into public realm works such as footpaths and cycle paths, especially in areas that will be redeveloped.

7 Comments on cost comparisons

BB and Arcadis separately reviewed the AECOM cost build-up Appendix E (BB with input from their quantity surveying department). Arup have not reviewed the rates. However, the following points should be highlighted (note differences may be due to differing assumptions):

- The AECOM rates are presented for “utilitarian” FRM structures, and there is an uplift applied for either brick or stone cladding to the walls themselves for the reaches. It is not clear whether the uplift is sufficient for particularly sensitive or high public-realm-value reaches. These rates have not been tested.

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- There are no rates for associated hard and soft landscape finishes in the vicinity of the walls. There is a lump sum allowance of 2% of the costed works to allow for this, but Arcadis suggest this is insufficient especially for epoch 3 “glass walls”, and we suspect insufficient for high-quality public realm works.
- BB rates for RC walls are below the EA rate adopted by AECOM, which may be due to the treatment of on-costs.
- BB rates for sheet piled walls appear significantly lower than the EA rate adopted by AECOM, even when BB allow for installation from a jack-up barge. Suspect this is due to the “all-in” costs built into the EA rates, hence anticipate the BB costs would increase if compared on a “like-for-like” basis. BB raise concern about the level of information provided to cost against.
- Sheet pile walls account for £3.17M (some 5% of the total costs) of the “low defences” (epoch 1 and 2), and an additional £3.6M in the “high defence” epoch 3 (~8% of the epoch 3 additional cost). Although these rates are taken from the EA Cost Estimation for fluvial defences summary of evidence, BB have reservations about the cost certainty of the sheet pile wall proposal [section 5.1 and Appendix 12 of the BB report]. However, even a doubling of cost of these elements would appear to have a minor impact on the full strategy costs overall (~6% overall increase).
- BB rates for contiguous piled wall reaches are significantly higher than the rates assumed by AECOM. Slightly under double the AECOM rate if driving from land, with further increase to $2\frac{1}{4}$ * the AECOM rate if installed from jack-up barges. Significant reductions are offered if different construction methods can be adopted, e.g. CFA piles or driven sheet piles (but note as outlined in Section 5 the rationale provided by AECOM may preclude some of these methods in certain reaches). Given the build-up from SPONS by AECOM and exclusion of prelims, risk or fee, etc. by BB these may both be an unfair comparison when compared with the “all-in from experience” rates used for the RC walls and sheet piled walls. It is not apparent whether BB have allowed for programme, logistical, environmental and consenting costs in deriving their rates for river-based working. Hence the reaches involving contiguous piled walls are likely to be subject to very significant cost uncertainty and probable overall cost increase if this construction method is retained.
- For all the contiguous-piled wall reaches, despite providing indicative pricing for a jack-up barge method, BB also questioned the feasibility of piling from a barge-mounted rig due to the bank profile. They proposed significant temporary works in the river to support a piling rig if access could not be obtained from the land side. The temporary works aspect does not appear to have been included in BB’s costing exercise, so costs may increase again.
- Wall raising is very briefly addressed in the BB study as a single line in Appendix 12.2. There is insufficient detail to accord any additional confidence in the AECOM costs than that provided by AECOM’s original work.
- BB did not comment on the rates for RC walls on piled foundations.
- BB rates for embankments generally lower than AECOM assumption, but based on re-use of material. Minimal impact on overall scheme costs due to very small proportion of scheme.
- Costs associated with building around or over existing outfalls and culverts were addressed by AECOM as a % allowance on the built-up costs. This was not tested by BB or Arcadis.

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- Minor aspects such as cladding, drainage and handrails are broadly in agreement or (in the case of handrail) would have minor impact on scheme overall cost.

8 Significant assumptions in terms of cost and programme on a reach-by-reach basis

Note the costs below relate to AECOM's Appendix E, excluding lump sums and optimism bias (these were added to the strategy totals for a "low defences" phase – Epochs 1 and 2, and a "high defences" phase – Epoch 3).

8.1 Entrance Lock

Low defences built in epoch 1 = £8.8M rising to £11.8M total in epoch 3 once high defences are built.

Of the low works the lock gate is £5M, flood walls £2.2M. Incremental increase to defence heights accounts for additional £3M in epoch 3. The new lock gate will be 10m high by 22 wide. BB have not specifically addressed the costs of the Entrance Lock gate, but did review the costs of Netham lock gate. If we take the same BB example (7m high, 10m wide) and factor the BB costs up in a similar, linear fashion but for both gate width *and gate height*, we arrive at costs reasonably close to the AECOM estimate. It appears the basic civil costs of extending or replacing the existing walls to accommodate such a gate are allowed for in the BB cost comparison. As such it appears that the gate costs do not appear unreasonable pending detail design, albeit costs associated with maintaining navigation access into the floating harbour, etc. (or consequential costs of stopping up navigation) during construction are not accounted for.

AECOM state that the alignment was chosen to cross the knuckle to reduce cost and reduce the impact on heritage walls around the perimeter. However, it is not clear whether the uplift for stone cladding is sufficient for high-spec finishes as this was not tested by BB or Arcadis. There is no allowance for high-spec surface finishing to provide a unified public realm design for the area. There is an opportunity to work on the alignment in conjunction with public realm works to improve the solution.

8.2 Cumberland Road

Low defences built in epoch 2 = £1.4M, rising to £6.5M total in epoch 3 once high defences are built.

Low defences are either new RC fin walls or extensions to Metrobus wall. Significant cost increase during epoch 3 due to introduction of contiguous piled wall.

Given the distance of the piling rig from the existing retaining walls in the epoch 3 it may be the case that the piling activities do not affect the existing riparian walls. However, BB anticipate a heavy rig (85 tonnes) which requires a piling mat. This would add significantly to the scheme costs and construction duration unless the existing road build-up (and services beneath) can be justified as the piling platform. If piling from the road is not acceptable (due to the likely need for a complete road closure during construction) then costs would increase due to the need for access from the

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river. On the current alignment the piling rig would then load the existing retaining wall, which is not feasible in its current condition (see below) or would require significant temporary works.

Potential cost variation is outlined in Section 7. Note also that in AECOM's preferred option selection report they state that "although the costing of the walls allows for a self-supporting design, capable of taking earth pressures from dead loads, the designs have not been tested for their ability to take additional loads from adjacent highways or railways". Hence the baseline cost for the contiguous piled walls may be un-conservative.

The chocolate path retaining wall is reported by AECOM (and then in more detail by CH2M) to be in poor condition, with a significant length having deformed noticeably since 2014 (rail line settlement) with further deformation having occurred in 2016 and again by December 2017. Refer to Section 6 for further comment on the possible opportunities to reduce or reassign the cost of reaches proposed as contiguous piled walls.

It appears that other than the disclaimer referring to railway loads, no account has been taken of other potential impacts that stem from interaction with the operators and users of the heritage railway. There is significant potential for scope creep, cost and timescale increases as these aspects are synthesised into a design for this reach.

8.3 Cumberland Road East

Low defences built in epoch 2 = £0.26M rising to £0.38M total in epoch 3 once high defences are built.

Minor costs. Any impacts insignificant overall. Floodgate, ramp and RC wall tie-ins. AECOM note no allowance has been made for construction works interaction with the heritage railway, in terms of access planning, condition monitoring, safety case, etc. so costs are likely to increase.

8.4 Commercial Road and Bathurst Dam

Low defences built in epoch 2 = £1.6M rising to £2.1M total in epoch 3 once high defences are built.

Major epoch 2 cost component is "frontline defence within river channel" @ £0.97M. Contiguous pile walls. Significant uncertainty in cost of this reach (albeit minor impact on overall scheme) as mentioned in Section 7. BB concerns about loading the existing wall with piling plant seem justified given that the piling rig is significant and the wall is reported to be in poor condition. Unsure about cost certainty of Bathurst dam raising – warning in AECOM Appendix E that a completely new dam may be required in epoch 3 which may impact cost of this section (albeit minor in overall scheme cost).

8.5 Clarence road

Low defences built in epoch 2 = £3.0M rising to £3.9M total in epoch 3 once high defences are built.

Entire epoch 2 cost component is "frontline defence within river channel" @ £3M. Contiguous pile to decouple new defences from existing retaining walls and provide the base for epoch 3 works. Significant uncertainty in cost as outlined in Section 7. BB suggest this could be done much more

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cheaply, slightly over 10% of AECOM cost assumption if done from land with CFA piling rig (subject to capacity checks on existing walls). BB introduced further uncertainty in the costs of carrying out the work by reference to existing retaining wall's historic failure (translation towards the river of over 100mm in 2014), albeit C2HM indicate that Clarence Road wall was repaired or re-stabilised following the 2014 tidal flooding event.

8.6 Cattle Market Road

Low defences built in epoch 2 = £0.9M rising to £1.1M total in epoch 3 once high defences are built.

Minor cost. Any impacts minor overall to the total strategy even if costs double. RC fin walls on piled foundation. Costs not tested by BB or Arcadis. AECOM note that liaison will be required with Network Rail as the proposals tie in to NR bridge walls. There is potential for the proposals to need refinement to meet NR requirements, e.g. to minimise vibration or ground movement within the zone of influence of the NR assets. This may add to cost and to any anticipated design and construction timescales for this reach.

Opportunity to investigate omission of piled foundation.

8.7 Totterdown and St. Phillips

Low defences in epoch 1 = £3.5M rising to £8.2M total in epoch 3 once high defences are built.

Due to the existing land uses and the constraints on access, the defences in this reach comprise many short lengths of reinforced concrete cantilever walls and sheet piles (for which there are "all-in" EA rates), but they also make use of existing buildings and boundary walls in the low defences scheme of epoch 1. Particular access difficulties and the bittiness of the solution in comparison with many of the other reaches, (and the necessary assumptions on the suitability of buildings to withstand flood loading), mean there is likely to be lower cost reliability in this section as compared to other reaches using these construction methods (e.g. entrance lock and parts of Netham).

Space is currently limited by adjoining properties and the strategy relies on taking land as the plots are redeveloped to construct the high defences as higher sheet pile walls. There is an acknowledged risk that this section may be upgraded "piecemeal" as a consequence of redevelopment timing, and also that many of the epoch 1 defences will be abandoned and replaced rather than extended in epoch 3. This explains the relatively high cost of epoch 3. Note also that in order to upgrade to high defences piecemeal, the low defence line will need to be maintained and tied into the high defences until the upgrade is completed. There is an opportunity to provide an area with enhanced connection to the natural river corridor in epoch 3 (refer to Section 6 for further comment).

8.8 Netham

Low defences in epoch 1 = £6.6M rising to £10.9M total in epoch 3 once high defences are built.

Existing sheet pile wall extended in epoch 1, replaced in epoch 3, and new RC walls on Feeder Road. Extending existing sheet pile walls for epoch 1 is deemed straightforward by BB, but the condition of the existing sheet pile walls has not been assessed.

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Major cost component of epoch 1 is a “high-defence height” lock gate at £5M. BB compared this to a similar example at Queensborough Creek and they have stated that the allowance appears adequate based on a straightforward linear multiplication based on the width of the gate.

The new lock gates are to be installed in a new lock structure (Preferred Option Development Report section 4.10.2 and Figure 10 of the Outline Design Report). The construction of the new lock appears to be only superficially addressed by a costing note in the AECOM Appendix E in which it is rolled into the gate cost. However, since the BB cost comparison included for “Civils RC sill and walls” at £750k within a total cost of under £5M, this is probably adequately covered.

A major component of epoch 3 is “frontline defence” at £3.5M, based on contiguous pile cost. Contiguous piles chosen because the existing defences are expected to have insufficient residual life to be incorporated in new long-life defences, and because the flood wall also has to act as a retaining wall and retain the existing riverbank. Significant uncertainty in this aspect of cost as for other contiguous pile reaches (BB state this reach can only be driven from river so their baseline rate is 2 1/4 * the AECOM assumed rate). BB proposed an alternative method of installing sheet piles in the river channel and filling behind with concrete, tying back with ground anchors. BB suggested this would be between one third and half the AECOM assumed rate for this reach.

Netham weir is mentioned in the Preferred Option Selection Report, table 13, as being important in maintaining the floating harbour water level. While the sub-structure and crest are currently in fair condition, the rock apron is in poor condition. Arup’s April 2018 review of the hydraulic modelling highlighted that there is modelling uncertainty around the Netham weir, which may have an as yet unquantifiable impact on the required defence levels in the area. Hence there is cost uncertainty in this reach until this aspect is better understood.

AECOM assume the rock apron will fail in 2065, which is the anticipated start date for epoch 3. Hence by epoch 3 it is likely that the weir will require additional work. AECOM have not allowed for any costs for works to the weir.

8.9 Detriment Mitigation

Low defences in epoch 1 = £2.6M rising to £3.6M “high”

Generally, detriment mitigation has not been a focus of any of the commissions to date. High cost uncertainty should be anticipated as the scope of this has not been adequately tested. This will be developed as part of the Arup’s strategy refinement commission.

The unit rate for raising walls at the paintworks accepts that raising gabions might be unsuitable for the high defences in epoch 3 and has allowed for complete replacement with higher RC walls in epoch 3. Opportunity to reduce overall spend marginally by raising to “high defences” straight away rather than attempting to raise the gabions by a smaller amount for epoch 1.

Netham South existing defences raising largest component at £1.9M in epoch 1. Extending existing sheet pile walls for epoch 1 is deemed straightforward by BB (extend the existing capping beam), but the epoch 3 works, currently envisaged as replacement with contiguous piled walls, are deemed difficult. Epoch 3 cost uncertainty as these contiguous piles were not costed at all by BB.

Bedminster PLP cost is very low at ~£35k. Even if this increased by a factor of 10 it would have negligible impacts on the cost of the scheme as a whole.

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9 Minor impacts that may accumulate

AECOM list a series of generic risks and impacts in Appendix E which have the potential to influence costs as the design progresses. These are not repeated here.

Back-of-wall drainage is included in AECOM's rates as a straightforward rate multiplied by the total defence length, which Arcadis report as being 1.1% of the total scheme cost. The build-up does not allow for differing construction methods, such as penetrating sheet piles or contiguous piles, or for collection chambers sited at the ends of such "impenetrable" reaches. Similarly, there is no specific allowance for flap-valves or flapping of (or construction around) existing outfalls that pass through the defence line. Costs associated with maintaining access to these after the defences are built were not addressed. This cost allowance may therefore be low, albeit significant changes in drainage cost appear unlikely to be significant to the overall cost of the scheme.



As mentioned in Section 7, while a rate has been applied for brick or stone cladding to the flood defence walls, this was not tested by Arcadis or BB and there is no account taken of public realm finishes. There is a potential for blanket increases across all the reaches due to these aspects not having been clearly taken into account.

Modifications to the sluices at Netham weir are required in epoch 3. They are reported as being in "poor" condition. These are costed at £50,000 but these costs are not explained by AECOM or tested by either BB or Arcadis. Given the low figure it appears AECOM anticipate minor modifications only. AECOM do not allow for any works to the weir itself.

Services diversions are specifically excluded from the AECOM rates except for itemised key assets. This seems sensible given one of the reasons AECOM cited for selecting front-line defences within the river channel was that this would avoid many of the existing services. It is likely that any apparent savings gained by refining the defence alignment would be partially offset by an increased cost and timescale impact of service diversions. Costs may increase if specific design and details for continued access to services affected by the alignments is required.

For similar reasons, tree removal or protection is not accorded a cost. Noteworthy risks are called off in caveats on reach by reach basis in Appendix E, but they are unlikely to significantly affect the overall cost of the scheme.

DOCUMENT CHECKING (not mandatory for File Note)

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Appendix G – Costing Estimate Report

It should be noted that the appendix in this report was issued in May 2020 to inform option costing and uplift of rates – they do not reflect the required extent of defences for the new Strategy. The costs presented in the SOC and this report should be referred to for the new Strategy.

Additional work has also been carried out to verify the costs of the lock and flood gates, based on supplier quotes and previous work, since this report was issued.

Bristol Flood Strategy - Cost Estimate Report 1

Cost Management



1. Executive summary

- The purpose of this report is to provide the client, Bristol City Council, with an update of the cost estimate produced by AECOM in 2017 for the River Avon Tidal Flood Risk – Management Strategy.
- There are four sections to this project:
 1. Costing of un-costed defences (additional to AECOM 2017 Preferred Option) – to be issued as a separate report.
 2. Updating of AECOM 2017 Preferred Option – to be issued as a separate report.
 3. Updating of AECOM 2017 preferred option for escalation.
 4. High level review of AECOM 2017 Preferred Option Costing.
- This report looks at 3 and 4, whereas 1 and 2 will be issued as a separate report.
- During the course of this report, the initial two sections are looked into in more detail, and these sections have been explained further.
- Arup have used indices found on the BCIS website to update rates that AECOM have used. Some rates have also been changed. Details of these changes have been noted in Section 3 and 4 respectively.
- Information used was sourced from the AECOM 2017 Preferred Option Development Report, the RICS website (BCIS) and the Cost Estimation for fluvial defences – summary of evidence (Environmental Agency). Arup’s in-house expertise were also used for any changes and assumptions.
- The AECOM cost, from the AECOM report with stated base date of 2015 was **£105,954,000**. This assumption was incorrect as all EA based rates utilised are 2009, and this has been corrected in Arup’s escalation assessment.
- The cost, uplifted to 2019, including correction of AECOM base date assumptions but before Arup’s sense check came to **£122,676,000**.
- The cost, uplifted to 2019, as above but including Arup’s sense check came to **£146,363,000**.
- Details of these uplifts can be found in the body of the report and a summary of costs can be seen in section 6.

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2. Methodology

What has been done in this report

- Arup referred to the report produced by AECOM in 2017 - River Avon Tidal Flood Risk Management Strategy, Preferred Option Development Report, which included the cost estimate.
- The Cost Management team at Arup were tasked with the following:
 1. Costing of un-costed defences (additional to AECOM 2017 Preferred Option) – to be issued as a separate report.
 2. Updating of AECOM 2017 Preferred Option – to be issued as a separate report.
 3. Updating of AECOM 2017 preferred option for escalation.
 4. High level review of AECOM 2017 Preferred Option Costing.
- In the estimate, sources of rates included; SPONS Civil Engineering and Highways 2016, Environment Agency estimation for fluvial defences (2009), Environment Agency estimation high cost premium solution 2008 (updated to 2015) and certain websites.
- According to the AECOM report, the base date mentioned for the Environment Agency report; delivering benefits through evidence: cost estimation for fluvial defences – summary of evidence, was 2015 as seen in Figure 1.
- Research was carried out to ensure that this base date was correct. Arup’s Cost Management team discovered that the base date was not 2015. The Long Term Costing Tool (Environment Agency) mentioned that the base date was 2009 as seen in Figure 2 (shown as an example for one of the items).

Figure 1: Screenshot of AECOM report

Defence maintenance costs

Defence maintenance costs have been developed from a number of sources, including:

- Environment Agency guidance for estimating maintenance costs for raised defences; Cost estimation for fluvial defences – summary of evidence, report SC080039/R2, Environment Agency 2015.
- Environment Agency System Asset Management Plan (SAMP) costs for system FR/14/SO69 Avon Netham to Avonmouth
- Costs for cathodic protection for frontline steel sheet piles

Source: River Avon Tidal Flood Risk Management Strategy - AECOM

Figure 2: Embankment Base Date

Volume based	2009	Updated costs
Very Small	£3,863	£5,184
Small	£1,826	£1,692
Medium	£1,243	£1,152
Large	£843	£594

Source: Long Term Costing Tool V12 - EA

2. Methodology

What has been done in this report

- As some of the data from the BCIS website was shown quarterly, February 2009 was chosen as the base date for the 2009 rates.
- Where rates were sourced from 2015/2016, February 2015/2016 was used as the base date respectively.
- The escalation was then carried out to May 2019, using indices from the BCIS website.
- An uplift was later done to 2024. Thereafter, an uplift was carried out to 2065. This is further discussed in section 3 and 6 of the report.
- Construction of this project is assumed to be a two year duration, therefore 2024 has been taken as the mid point for escalation calculation.
- Arup have incorporated the fluvial component into the updated flood risk analysis and have proposed additional and higher defences. The Cost Management team looked at updating the costs for the proposed scheme. Arup built on what AECOM had produced. Where rates or quantities have been changed, Arup have taken note of this and the reasons for these changes have been noted too. Arup have only looked at costs and no changes to quantities have been made.
- With regards to the high level review, Arup have looked at the rates used by AECOM, which were discussed and analysed. Following a high level review, it was decided that some of the rates previously used were not appropriate. This can be seen in section 4 of this report.

3. Updating AECOM 2017 Preferred Option for escalation

What Arup have done

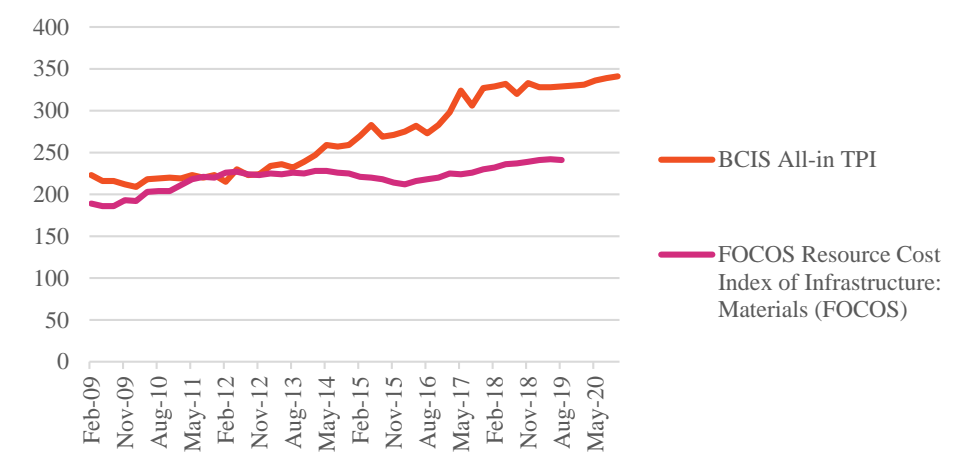
- Arup’s Cost Management team used the BCIS website to download different indices that would relate to the project which included; concrete, reinforcement, labour, excavation, General Civil Engineering Cost Index, Tender Price Index and many more.
- Looking back at the previous report, Arup’s Cost Management team noticed that different base dates were used when preparing the cost estimate.
- The different base dates included; 2009, 2015 and 2016.
- After further research by the team, findings were as follows:
 1. The 2009 rates were sourced from an Environment Agency (EA) report; delivering benefits through evidence: cost estimation for fluvial defences – summary of evidence.
 2. 2015 rates were sourced from an EA cost estimation high premium solution (2008 uplifted to 2015), as well as SPONS Civil Engineering & Highways Works 2015.
 3. 2016 rates have been sourced from SPONS Civil Engineering & Highways Works 2016.
 4. Where base dates were not found, the base date was assumed to be 2015.
- The base date for 2009 rates was assumed to be February 2009 for rates from the Environment Agency fluvial defence report. This date was chosen because the base date was shown as 2009 in the Long Term Costing Tool and some of the data from BCIS only began in February 2009.
- Where rates are known to be sourced from 2015 or 2016, February 2015/2016 was used as the base date in order to be consistent.
- Due to some data only being available till May 2019, the forecasted date was May 2019.
- After looking at the BCIS indices, graphs were prepared to help with the analysis of the data. All indices were compared with the trend shown by the BCIS all-in Tender Price Index. All graphs generally showed a similar trend and therefore, the team assumed it would be accurate to use. This can be seen in Figure 6.
- Using information found on the RICS website, rates were forecasted to 2024, as this is when forecasted information was available until – the latest forecast period: 2nd quarter 2019 to 2nd quarter 2024 (<https://www.rics.org/uk/news-insight/latest-news/news-opinion/civil-engineering-forecast/>).
- Table 1 summarises the different base dates and the uplift factors used to escalate the rates to 2019 and 2024.
- Further uplifts from 2024 to 2065 have been calculated assuming a 3% per annum figure.

3. Updating AECOM 2017 Preferred Option for escalation

Escalation to 2019

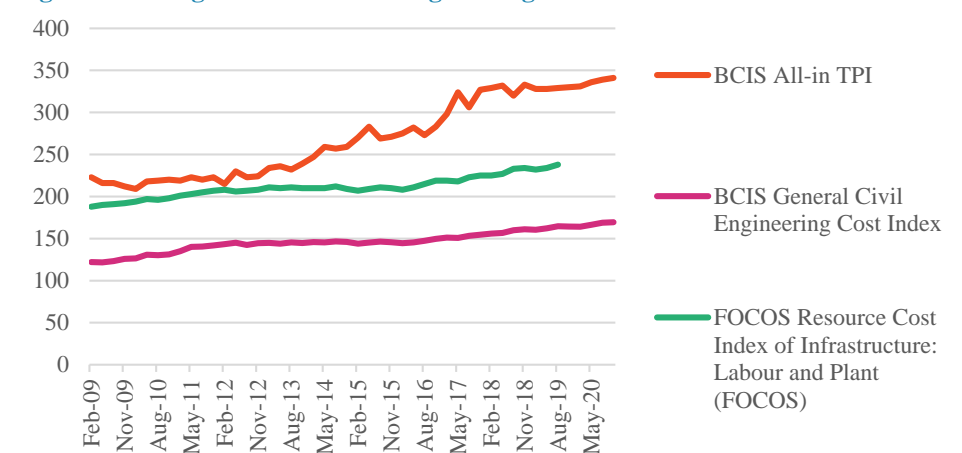
- An uplift factor from the 2009 base date (February 2009) to May 2019 was taken for each of the indices mentioned before. An average was then taken, which was 1.27. This can be seen in Table 3.
- As seen in Figure 5, there was generally an increase in the factors from February 2009 to May 2019. The rates were then uplifted accordingly.
- The same was done for the 2015 rate updates, and an average of 1.13 was used. For rates from 2016, the BCIS General Civil Engineering Cost Index was used to uplift the rates. This gave an uplift factor of 1.13.
- According to Figure 3, FOCOS (materials) showed an upward approach until February 2014, where a downward approach began. Around December 2015, it began to have a steady increase. After September 2018, the trend seemed to have followed the BCIS Tender Price Index trend. Therefore, FOCOS (material) was deemed accurate enough to use.
- As FOCOS materials was used, the materials index was discarded. This is because if it was used, there would be a double counting factor. Therefore, by discarding the materials index, a more accurate average was found.
- Figure 4 shows the BCIS TPI against the Civil Engineering Cost Index and FOCOS trends. As seen by the trends, the BCIS General Civil Engineering Cost Index and FOCOS (combined) lines show a general increase. The BCIS TPI also showed a general increase, with a few peaks and troughs.
- Overall, as the TPI and General Civil Engineering Cost Index generally followed a similar trend to the BCIS, both were used, when calculating the average uplift factor.

Figure 3: TPI against FOCOS (materials)



Source: BCIS website

Figure 4: TPI against BCIS Civil Engineering Cost Index and FOCOS



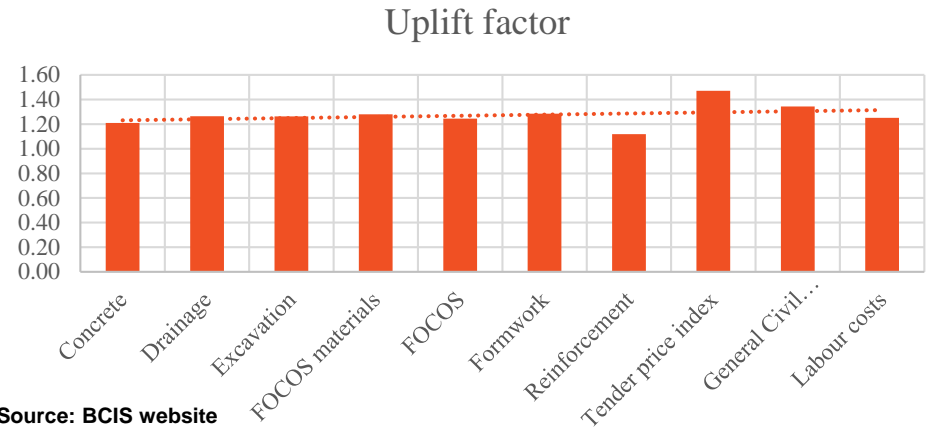
Source: BCIS website

3. Updating AECOM 2017 Preferred Option for escalation

Escalation to 2019

- Figure 5 shows a line graph of all the uplifted factors. A line of best fit was added to show that generally, there was an increase in the indices and therefore, the rates were uplifted accordingly.
- Figure 6 shows the index comparison for indices that Arup thought would be relevant to this project. This graph shows a visual representation of the trends that each of the indices have shown and can be used to compare against the BCIS Tender Price Index.
- As steel is variable, its index has a lot more peaks and troughs compared to the other indices as seen in Figure 6.

Figure 5: Uplift factors



Source: BCIS website

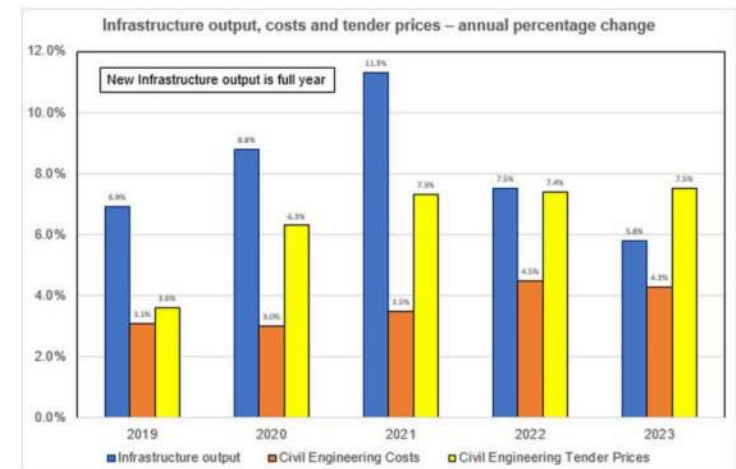
Source: BCIS website

3. Updating AECOM 2017 Preferred Option for escalation

Forecasting to 2024 and 2065

- Figure 7 shows an extract from the RICS website for the Civil Engineering Forecast. It shows some trends for infrastructure output, Civil Engineering Costs and Civil Engineering Tender Prices.
- When forecasting the costs from 2019 to 2024, the Civil Engineering Forecast was used.
- On the RICS website, an uplift factor of 1.20 was given to uplift rates from 2019 to 2024. This was the factor that was used by Arup to forecast the cost in 2024.
- Some assumptions that these forecasts were based on include; The UK remains a member of the EU but with no voting rights from the end of the extended period following the signing of Article 50, i.e. from 1st quarter 2020. There will be a two-year transitional period. While the transition period is set to end in December 2020, it can be extended once if agreed before 1 July 2020. There will be an extension of two years with continued payments to the EU (which will be deducted from the final 'divorce bill'. Following the end of the transitional period, any trade agreements with the EU are less favourable than before the EU Referendum. Other assumptions are found on the website (link provided on page 6).
- Escalation from 2024 to 2065 is difficult to forecast with any degree of certainty due to the many unknowns over such an extended period. We have therefore based escalation from 2024 to 2065 on an assumed 3% per annum.
- This report presents current and escalated costs for phased construction, assumed to take place in 2024 and 2065. Arup cannot find any evidence that AECOM have escalated costs in any way.
- In accordance with the guidance issued by DEFRA/EA set out in the document “Environment Agency – Flood and Coastal Erosion Risk – Management Appraisal Guidance” AECOM have used current costs, with no allowance for future cost increases (“Nominal Costs”). This assumes that there is no escalation in future construction costs. This does not represent a realistic cost. There is an alternative method, using discount rates that include allowances for escalation (“Real Costs”).
- As requested, this report presents escalation costs only and present value calculations have not been carried out.

Figure 7: Annual percentage change



Source: ONS, BCIS (RICS website)

3. Updating AECOM 2017 Preferred Option for escalation

Summary

- Table 1 summarises the base dates, escalation date and all the uplift factors used.
- Base dates are February 2009, February 2015 and February 2016.
- To uplift costs to May 2019, the uplift factors 1.27, 1.13 and 1.13 were used respectively.
- From May 2019, 1.20 was used as the uplift factor, to uplift costs to 2024, as shown on the RICS website.
- From 2024, 3% per annum was used to forecast costs to 2065. This gave an uplift factor of 4.03 from 2019 costs.

Table 1: Summary of uplift factors

Base date	February 2009	February 2015	February 2016
May 2019 Uplift factor	1.27	1.13	1.13
Variance	-11%		0%
2024 Uplift factor from May 2019	1.20		
2065 Uplift factor from 2019	4.03		

4. Sense check of AECOM 2017 Preferred Option Costing

Detailed look at the rates used

- In terms of sense checks, the Cost Management team at Arup looked at the rates that were already provided by AECOM.
- For the rates, different sources were used, for example SPONS Civil Engineering and Highways 2016, Environment Agency estimation for fluvial defences (2009), Environment Agency estimation high cost premium solution 2008 (updated to 2015) and certain websites. Where possible, the Cost Management team double checked that the rates were sourced from where it was stated. Where the rates could not be found (e.g. from the websites), it was assumed that the source of the rates were correctly stated.
- Arup noticed that the rate for steel used by AECOM was £609.35/t which seemed too low. Therefore, using internal cost data and SPONS 2016 pricing book, Arup proposed to use £1,200.00/t.
- The Overheads and Profit percentage used by AECOM seemed to have only been applied to contiguous piled walls. Arup have applied it across all items. It accounts for preliminaries, overheads and profit.
- Table 2 shows the summary of changes, made by Arup. This was done in order to give the client a summary of the design updates made by Arup, after the sense check was completed. As seen in table 2, the steel rate used by AECOM was changed to a more reasonable rate.
- Arup considered the diameters of the links – 25mm, 20mm and 32mm to be unrealistic. Usually, links are around 8mm, 10mm or 12mm in diameter. However, this quantity has not been changed.
- The tanking rate was also changed to £134/m² using SPONS Architects and Builders 2019 as the source.

Table 2: Summary of change

Change	Detail
1. Steel rate	Rate for steel has been changed from £609.35/t (used by AECOM) to £1,200.00/t
2. OHP percentage	The 25% OHP used by AECOM was for contiguous piled walls only. This has been removed and 25% has been applied to the sub total, therefore being applied to all rates.
3. Tanking rate	Tanking rate was changed from £200/m ² used by AECOM to £134/m ² (2019 rate) using SPON'S 2019 Architects and Buildings.
4. Lock gate cost	Lock gate costs were changed from £5,000,000 to £2,460,000 obtained from a specialist contractor, including all other associated costs.

4. Sense check of AECOM 2017 Preferred Option Costing

Detailed look at the rates used

- AECOM included the lump sum of £5,000,00 for the replacement of Lock Gates. Arup have investigated this item further and have received a budget quotation for the supply and transportation of larger gates from Ravenstein for the sum of £1,250,000. Adding allowances for installation, MSE outfitting and removal of the existing gates, Arup estimate a total cost of £2,460,000, details of which are included in Table 2.
- AECOM have included an optimism bias of 60%. They have followed the guidance issued by DEFRA/EA set out in the document “Environment Agency – Flood and Coastal Erosion Risk – Management Appraisal Guidance” which simply recommends the adoption of 60%. As also recommended, AECOM have attempted to back-up this figure with a Quantified Risk Assessment (QRA), which according to the ARCADIS report may have been badly executed. We also have some concerns on the methodology adopted, although there is insufficient detail to confirm this. At this stage we do not propose to duplicate the QRA as this would require significant additional resources. In summary:
 1. AECOM have adopted the 60% figure correctly from current DEFRA/EA guidance
 2. The QRA may not have been correctly executed
 3. UK Government Green Book guidance for a standard civil engineering construction would suggest a figure of 44%
 4. Without further work, Arup recommend that the 60% Optimism Bias be retained

6. Conclusion

Summary

- To conclude, each of the uplift factors from 2009 to 2019, seen in table 3, were looked at and a general trend was shown by all factors. Therefore, the average (average taken to account for lower factors) used was 1.27 to uplift rates from 2009.
- For 2015 and 2016, 1.13 was the uplift factor used to uplift rates to 2019.
- This gave up to date rates, which were then used to escalate the costs for the preferred option.
- The Civil Engineering Forecast, from the RICS website was used to forecast costs from 2019 to 2024, using the 20% escalation.
- 3% per annum was used to further forecast costs from 2024 to 2065. As seen in table 4, 4.03 was the uplift factor calculated from 2019 to 2065.
- All lump sump percentages are assumed to be the same as in the AECOM estimate:
 - Environmental Mitigation "coastal squeeze" (compensatory habitat) - 1%
 - Environmental Mitigation other - 1%
 - Investigations (ground, topo services etc) - 5%
 - Business Case, detailed design, project management, site supervision and all other client and consultancy salaries and fees - 20%
 - Compensation - 5%
 - Compulsory Purchase - 10%
- Optimism bias is also assumed to be the same – 60% as discussed on p. 13.
- Arup have added a uniform 25% to cover overheads and profit and contractor preliminaries, which are not included in AECOM rates, other than in the contiguous pile rates, which has been removed.

Table 3: Uplift factors from 2009 to 2019

Index	Uplift factor
Concrete	1.21
Drainage	1.26
Excavation	1.26
FOCOS materials	1.28
FOCOS	1.24
Formwork	1.29
Reinforcement	1.12
Tender price index	1.47
General Civil Engineering Cost index	1.34
Labour costs	1.25
Average	1.27

Table 4: Uplift factors summary

Detail	Uplift factor
Uplift factor from 2015 to 2019	1.13
Uplift factor from 2016 to 2019	1.13
3% per annum after 2024 (1.20 used from 2019-2024)	4.03

6. Conclusion

Summary

- Table 5 shows the summary of the AECOM costs (with no stated base dates), AECOM costs escalated to 2019 base date and AECOM costs escalated to 2019 base date with Arup sense check on rates. All assume the AECOM quantities.
- There is no comparison of costs in 2024 and 2065 as AECOM did not present phased costs for these years so Arup are unable to establish the quantities applicable to each period for cost comparison purposes.
- The escalated costs for the phased construction based on Arup’s engineering and costing is presented in Report 2.

Table 5: Summary of costs

	AECOM costs	2019	2019
	Base dates 2009, 2015 and 2016	Escalation of AECOM costs	Escalation of AECOM costs after Arup sense check
Low Defence Total	£61,651,000	£70,604,000	£80,386,000
High Defence Total	£44,303,000	£52,072,000	£65,977,000
Total	£105,954,000	£122,676,000	£146,363,000

Note that 'low defences' encompasses works in 2015 and 2030 for AECOM, and works in 2025 for Arup. 'High defences' refer to 2065 in both cases.

7. References

- BCIS Civil engineering forecast:
 - <https://www.rics.org/uk/products/data-products/insights/civil-engineering-forecast/>
- BCIS website for indices:
 - <http://service.bcis.co.uk/BCISOnline>
- Environmental Agency estimation for fluvial defences:
 - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/411171/Cost_estimation_for_fluvial_defences.pdf
- Environmental Agency long term costing tool:
 - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/411166/Long_term_costing_spreadsheet_tool.zip
- SPONS Pricing book: SPONS Civil Engineering and Highways Works Price Book 2016.

Appendix H – Delivery Risk Register

Version number		2.0	Project M		Robin Campbell							
Risk ID	Risk description		Risk status	Risk owner	Response Action			Qualitative Ranking (After Response Action)				
	Source of risk	Consequence on project			Existing safeguards in place	Action	Action owner	Probability scale	Cost impact	Time impact	Cost+time impact	Priority
Strategy - Engagement												
1	Perception of low general awareness of risk/problem strategy seeks to address.	Delay/challenge to flood strategy adoption/delivery.	Live	BCC	Non-technical summary under preparation	Supportive engagement and awareness raising to complement consultation.	BCC/Arup	L	L	H	H	M
2	Consultation procedural risks	Delay/challenge to flood strategy adoption/delivery. Perception of limited ability to influence strategy outcome or predetermination.	Live	BCC	Non-technical summary under preparation	Clarity of consultation language/timing. Political briefings kept to high-level informing/data gathering in advance. EA technical assurance in advance of consultation analysis c	BCC/Arup	L	L	VH	VH	H
3	Adverse PR. Engagement to date limited during extensive technical assessment. Consultation on strategy timed as following technical assessment.	Delay/challenge to flood strategy adoption/delivery. Reputational risk conflicting Council's commitment for early engagement. Lack of trust and opportunity to build consensus. Perception of limited ability to influence strategy outcome.	Live	BCC	Lessons from Cork shared.	Clarify strategy forms preliminary roadmap, with development, engagement and consultation planned at subsequent scheme case and then design stages.	BCC	M	L	H	H	H
4	Stakeholders may miss-understand evidence. Strategy relies on complex evidence base of extensive number of studies by range of consultants.	Delay/challenge to flood strategy adoption/delivery.	Live	BCC	Non-technical summary under preparation	Steer sought for basis of technical evidence being shared/retained.	BCC/Arup	M	M	M	M	M
5	Lack of political consensus, noting strategy adoption in advance of mayoral election May 2021	Delay/challenge to flood strategy adoption/delivery.	Live	BCC	Non-technical summary under preparation. Briefings planned.	Seek cross-party consensus	BCC	M	L	H	H	H
Strategy - Consenting & Approvals												
6	Strategy endorsement by Environment Agency Regional Director or adoption by BCC Cabinet delayed	Delay to flood strategy adoption/delivery.	Live	BCC	Programme of briefings and reporting planned. Clear governance structure agreed.	Ongoing programme governance.	BCC / EA	M	L	VH	VH	H
7	Strategy fails to demonstrate reasonable prospect of delivery	Limited change to consideration of flood risk in strategic and site specific planning terms (requires enabling infrastructure to have reasonable prospect of delivery).	Live	BCC	Funding strategy under preparation	EA assurance to be sought.	BCC / EA	L	L	H	H	M
8	BCC - EA Legal Agreement for delivery of strategy (use of stat. powers, maintenance responsibilities)	Delay to flood strategy delivery.	Live	BCC	Lessons from examples such as Derby sought. Precedence of Junction Lock MOU. Paper on powers and maintenance responsibilities prepared.	Review at OBC stage	BCC / EA	L	L	H	H	M
Strategy - Funding												
9	Insufficient capital funding (phase 1 or 2) - either due to insufficient budget estimates by Strategy (eg inflation) or unaddressed significant funding gap. Wider austerity/funding challenges.	Delay to flood strategy delivery. Limited change to consideration of flood risk in strategic and site specific planning terms (requires enabling infrastructure to have reasonable prospect of delivery).	Live	BCC	Strategy key to wider growth and regeneration proposals. Strategy includes benchmarked/reviewed cost estimates with optimism bias allowance. Funding Strategy update identifying possible funding mechanisms. EA business case assurance.	EA and BCC funding team support. OBC to develop funding stream for phase 1 works.	BCC, EA & Future Consultant	M	M	VH	VH	H
10	Insufficient revenue funding between EA and BCC wrt maintenance liabilities	Delay to flood strategy delivery.	Live	BCC	Lessons from examples such as Derby sought. Precedence of Junction Lock MOU. Paper on powers and maintenance responsibilities prepared.	Review at OBC stage	BCC / EA	M	L	L	L	L
11	Change in flood defence grant arrangements	Delay to flood strategy delivery.	Live	BCC	SOC based on 2021-2027 partnership funding rules	Review and monitor	BCC / EA	M	L	L	L	L
12	Strategy assurance	Delay to flood strategy adoption/delivery.	Live	BCC	Interim project team assurance sought. EA assurance by LPRG planned with float.	Review and monitor	BCC / EA	L	L	H	H	M
13	Insufficient funding for wider benefits or placemaking extra-over approach	Delayed/unrealised opportunities for wider benefits	Live	BCC	Provide a range of placemaking options and indicate 'low' and 'high' costs	EA and BCC funding team support. OBC to develop funding stream for phase 1 works.	BCC & Future Consultant	M	L	L	L	L
Strategy - Evidence base												
14	Climate change impact projections/guidance changes	Impact on defence levels/benefits, and timing of future phases.	Live	BCC	Allowances to use have been agreed with EA and BCC	Monitor and review, with strategy to define triggers	BCC/Arup	H	L	L	L	M
15	Hydraulic modelling assumptions/confidence	Reduces confidence in analysis	Live	BCC	Modelling at strategic level. Assumptions agreed with EA and BCC. Precautionary approach. Joint probability used for funding. New gauging installed at Redcliff.	Review at OBC stage. Guidance on hydrology, joint probability and extreme waterlevels anticipated to change over life of strategy.	BCC & Future Consultant	L	L	M	M	M

16	Future OBC and design stages derive a significantly different freeboard allowance from the nominal 300mm used to date in the SOC	Change to costs and impact.	Live	BCC	SOC used best initial estimate (0.3m)	Review at OBC stage	BCC & Future Consultant	L	L	L	L	L
17	Environmental assessment extensive. To keep proportionate, latest iteration by Arup only a partial update of the SEA documents undertaken by AECOM. Pre-Scoping Report (Activity 9C) has not been updated in line with the amended Strategy. The baseline information for the project was not updated for the SEA addendum and remained as per the 2017 submission, with exception of the Heritage Assessment	Elements of the SEA won't be as up to date as the Environmental Report. Inconsistency of information if used for consultation. The baseline information is no longer relevant.	Live	BCC		Environmental baseline and assessment to be updated further at OBC stages	BCC / Future consultant	L	L	M	M	M
18	The SEA Addendum considered the placemaking strategy but the assessment was undertaken based on the FCERM baseline approach.	Inconsistency of information if used for consultation.	Live	BCC		Environmental documentation to be updated further at future stages with better definition of placemaking strategy	BCC / Future consultant	M	L	M	M	M
19	Challenge to technical assessment leading option (Phased raised defences)	Delay/challenge to flood strategy adoption/delivery.	Live	BCC	Non-technical summary under preparation. Evidence base robust and considered wider case for alternatives such as tidal barrier delivering tidal energy or transport crossing.	Steer sought for basis of technical evidence being shared/retained.	BCC	L	L	M	M	M
Strategy - Interfaces												
20	Stakeholder confusion over interface with other projects (themselves with various stakeholder concerns)	Delay/challenge to flood strategy adoption/delivery.	Live	BCC	Clarity of messaging. Governance agreed.	Governance. Clarity of consultation language/timing. Political briefings kept to high-level informing/data gathering in advance.	BCC/Arup	M	M	M	M	M
21	Local Choice for accelerated flood strategy timing/phasing due to interface with other projects (increase funding gap)	Limited change to consideration of flood risk in strategic and site specific planning terms (requires enabling infrastructure to have reasonable prospect of delivery).	Live	BCC	Governance agreed.	Governance.	BCC/EA	M	M	M	M	M
22	Interface with other sources of flood risk - surface water and sewerage. Known surcharging etc Albert Road.	Additional cost (eg non-return valves)	Live	BCC	Strategy considers surface water and sewerage interface at strategic level, ensuring no increase in risk.	Engage Wessex Water. Review at OBC stage.	BCC	M	L	L	L	L
23	Interface with EA assets at Pill / Shirehampton /Keynsham / Bristol Frome	Interface with existing asses/emerging proposals	Live	BCC	Ongoing engagement.	Engage with EA (wrt emerging SOCs for River Frome and Markham Brook, maintenance at Pill) and BANES (wrt Keynsham strategic growth/regeneration proposals)	BCC/EA	M	L	M	M	M
24	Funding/integration - Interface win-win opportunities missed. Obstruction - flood strategy defences footprints clash with development/proposals (or vice versa). E.g Western Harbour and BTQ	Missed partnership funding contributions. Abortive work increasing cost and/or changing alignment/form of defences.	Live	BCC	Council actively managing interfaces. Successes include future-proof Chocolate Path repairs. Governance agreed.	Governance. Strategy not reliant on developments however emerging policy framework to enable development(s) to deliver elements	BCC/EA	M	M	M	M	M
Schemes - Consenting												
25	Non-acceptance/delayed acceptance by statutory consultees (HE, NE, BCC, BANES, South Glos, North Somerset - Highways Authorities, Harbour Authorities etc)	Programme delay and potential increase in costs for additional studies/mitigation measures.	Live	BCC	Engagement to gain buy-in and support during Strategy development.	Further engagement through strategy consultee working group. Voluntary EIA, full HRA and WFD planned.	BCC & Future Consultant	L	L	H	H	M
26	Landowner/occupier agreements protracted/delayed. Areas of land unregistered (eg St Philips Avon Path)	Programme delay and potential increase in costs for additional studies/mitigation measures.	Live	BCC	Default flood strategy option minimises requirement for works on third-party (i.e. nonBCC) land. Budget estimate includes compensation allowance including compounds and working access.	Early identification of likely landowner agreements and early engagement	BCC & Future Consultant	M	L	VH	VH	H
27	Challenge to scheme(s) consenting due to perception of flood risk impact on third-parties	Programme delay and potential increase in costs for additional studies/mitigation measures.	Live	BCC	Detriment mitigation developed in consultation with EA.	Engage affected communities, identifying opportunities for win-win (eg Pill wall repairs and Keynsham development strategy)	BCC & Future Consultant	M	L	H	H	H
28	Impedement of navigation and quay access	Programme delay and potential increase in costs for additional studies/mitigation measures.	Live	BCC	Liaison with harbourmaster.	Engage with Harbourmaster and operators during OBC and design stages, identifying mitigation.	BCC & Future Consultant	L	M	M	M	M
Schemes - Engineering												
29	Utilities (known/unknown) interface with proposals	Potential significant increase in costs/delay or changes to proposed alignment/form.	Live	BCC	Budget estimate optimism allowance with desk study of information from previous BCC projects.	Review at OBC stage. Surveys and engagement with utility owners.	BCC & Future Consultant	L	M	L	M	M
30	Ground conditions including risk of Unexploded Ordnance and Contamination	Potential significant increase in costs/delay or changes to proposed alignment/form.	Live	BCC	Strategy sought to adopt precautionary approach using available GI and adjacent designs (eg Chocolate Path)	Review at OBC stage. Ground investigation at detailed design stage (inc. UXO search).	BCC & Future Consultant	M	M	M	M	M
31	Procurement delays. Late contractor involvement.	Potential significant increase in costs/delay.	Live	BCC	SOC includes indicative procurement options, including ECI options.	Procurement strategy to be developed	BCC	M	M	M	M	M
32	Ground permeability may be high, affecting the effectiveness of defences by allowing water to propagate underneath them.	Effectiveness of defences may be reduced. Potential to lead to remedial construction works	Live	BCC	Some early assessment of ground conditions has been carried out.	Allow for piled / deep foundations in initial designs. Specific assessment and GI to be undertaken at next stage.	BCC & Future Consultant	M	M	M	M	M
33	Working with heritage / ageing assets (eg riparian retaining structures in varying/poor condition). Risk of asset failure (eg Chocolate Path and Clarence Road recent collapses). Insufficient information on existing structures.	Potential significant increase in costs/delay or changes to proposed alignment/form.	Live	BCC	Budget estimate optimism allowance with desk study of information from previous BCC projects. BCC Harbour Condition Assessment ongoing interim findings reviewed by strategy.	Review at OBC stage with design, surveys and contractor engagement	BCC & Future Consultant	L	M	M	M	M

34	Detriment mitigation proposals subject to design development eg -Chapel Way defence may cause surcharging of drainage; -Uncertainty in ground levels at new housing estate adjacent to Malago drive; -Uncertainty in ground levels at Crew's Hole Road defence; -Additional measures may be required further upstream of A4174	Additional optioneering and/or design work. Potential delay and increase/reduce costs. Unknown environmental impacts resulting from detriment mitigation U/S A4174.	Live	BCC	SOC recognises risk.	Review at OBC stage with design, surveys and contractor engagement including: - review connections to the culvert - incorporate housing estate ground levels into model - survey Crew's Hole ground levels - U/S A4174	BCC & Future Consultant	M	M	M	M	M
35	Flood strategy interface with rail assets - At Bower Ashton (reach 10) the railway acts a conduit during flooding events - At Sea Mills the railway bridge across the River Trym is at risk of getting flooded in 2065 as the soffit level is below the FCERM 2065 FDL. - Flood gate across heritage railway - Flood wall adjacent to Temple Meads abutment	Flooding of the railway will cause flooding to properties either side of the railway.	Live	BCC	SOC recognises risk.	Next stage to include engagement with Network Rail to explore opportunities to assist in their protection of their asset	BCC & Future Consultant	M	M	H	H	H
36	Damage (or risk of damage) to third-party structures (eg adjacent buildings)	Potential significant increase in costs/delay or changes to proposed alignment/form.	Live	BCC	SOC recognises risk and adopts precautionary approach.	Review at OBC stage with design, surveys and contractor engagement	BCC / Future consultant	M	M	M	M	M
37	Asset maintenance requirements/access yet to be defined.	May require redesign or additional land take	Live	BCC	SOC recognises risk and adopts precautionary approach.	Review at OBC stage with design, surveys and contractor engagement	BCC / Future consultant	M	M	L	M	M
Schemes - Environment												
38	The amended Strategy contains a number of direct impacts on heritage assets. Risk of archaeology	Potential requirement for consent from Historic England/LPA. Potential significant increase in costs/delay or changes to proposed alignment/form.	Live	BCC	Heritage baseline and assessment completed.	Environmental documentation to be updated further at future stages. Engage with HE.	BCC / Future consultant	M	M	H	H	H
39	Environmental impacts deemed too great or inadequately mitigated	Potential significant increase in costs/delay or changes to proposed alignment/form.	Live	BCC	SOC adopts precautionary approach with budget allowance for mitigation	Design, engagement, consultation and further environmental assessment proposed in future stages.	BCC / Future consultant	L	M	H	H	M
40	The design of detriment mitigation measures has been undertaken to a different level of detail in comparison to the flood defence design	The impacts reported within the Environmental Report may change on closer inspection	Live	BCC	SOC recognises risk.	Environmental documentation to be updated further at future stages, following greater definition of these defences	BCC / Future consultant	M	M	H	H	H
General Risks												
41	Widespread flood event	Change in project direction with implications on scope, programme and cost	Live	BCC	Communication with BCC and Council leadership	To maintain awareness of the political landscape	BCC	M	M	M	M	M

Appendix I – Preliminary sizing of flood defence at Eastern Corridor (BTQ)

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Subject Preliminary sizing of flood defence at Eastern Corridor – Rev 03

1 Introduction

As part of the Bristol Flood Strategy project, Bristol City Council is exploring options to combine an improvement in the flood defences with placemaking opportunities along the River Avon. In Reach 7 – referred to as Bristol Temple Quarter, Totterdown or St Philip’s Marsh – flood defence structures will reduce the width of the existing path along the North bank of the river. The site is also quite constrained in terms of access and unstable geotechnical conditions.

Bristol City Council has instructed Arup through CEE028 to carry out a high-level study to:

1. Determine if it is feasible to construct defence structures within the existing river corridor (i.e. without additional land purchase) in Reach 7 given the site constraints; and
2. Obtain a more accurate estimate of the possible reduction in path width if defences are feasible.

2 Assumptions

The following assumptions were used to carry out the preliminary sizing of the flood structures:

- Flood defence level of 10.2mAOD for 2065 FCERM level.
- Existing path width of 1.5m and 3m representing the minimum and maximum width found along the path respectively.
- Existing ground level of 8.3mAOD as representative lower bound for the path, based on station levels in topographic survey drawing number 194/7282/2C by Anthony Brookes Survey Ltd on Aug 2013.
- River bank slope starts at edge of path with a downward slope angle of 45°. Assume the river banks remain stable throughout construction.
- Existing structures cannot be relied on for flood protection. Minimum separation of 200mm required from existing structures on landside to avoid damage during construction.

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- Ground conditions as summarised in Section 3. A detailed ground investigation should be carried out to inform later stages of the design.
- Detrimental impacts of negative skin friction on the capacity of piles not considered.
- 5m pile socket length into bedrock layer, based on discussions with piling contractor.

Based on all of the above assumptions, the representative cross-section used is shown in Figure 1.

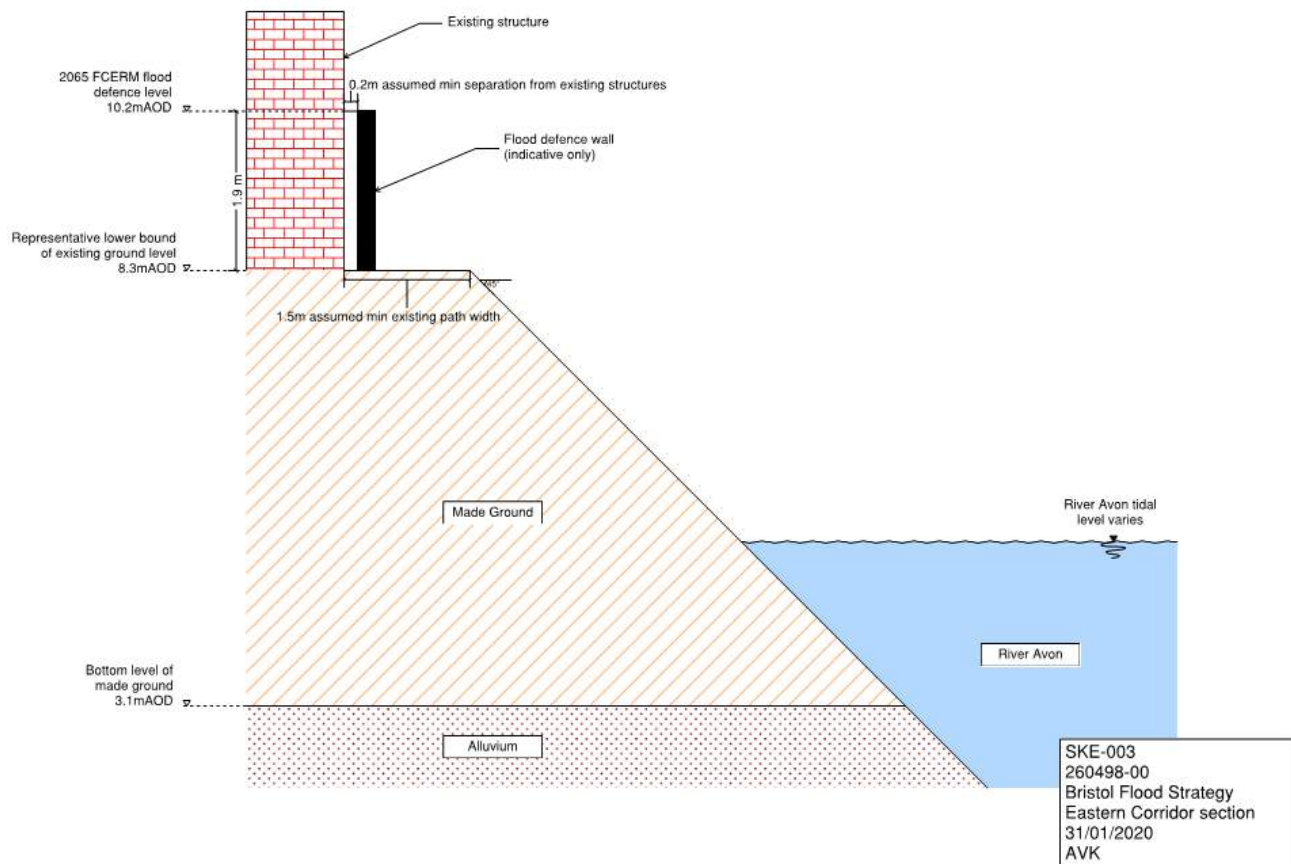


Figure 1 - Representative cross-section.

3 Constraints

3.1 Path width

The path is currently designated as a 'greenway' rather than a Public Right of Way and has part of recreational and national cycle network routes along its length. Although the "greenway" has no status, there are various mechanisms by which the path could be deemed a Public Right of Way. As such, BCC has advised that the path width should not be reduced where possible. Sustrans Greenway Design Guidance suggests an absolute minimum width for a shared use greenway of 2.5m and preferred minimum of 3m. However, some sections along the footpath in Reach 7 are currently already less than 2.5m wide and they account for approximately 30% of the total 1500m that comprise Reach 7. Figure 2 shows how they may be affected by a flood defence wall with an assumed width of 400mm.

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Any new structures constructed along the path must reinstate or provide new edge protection on the side closest to the river.

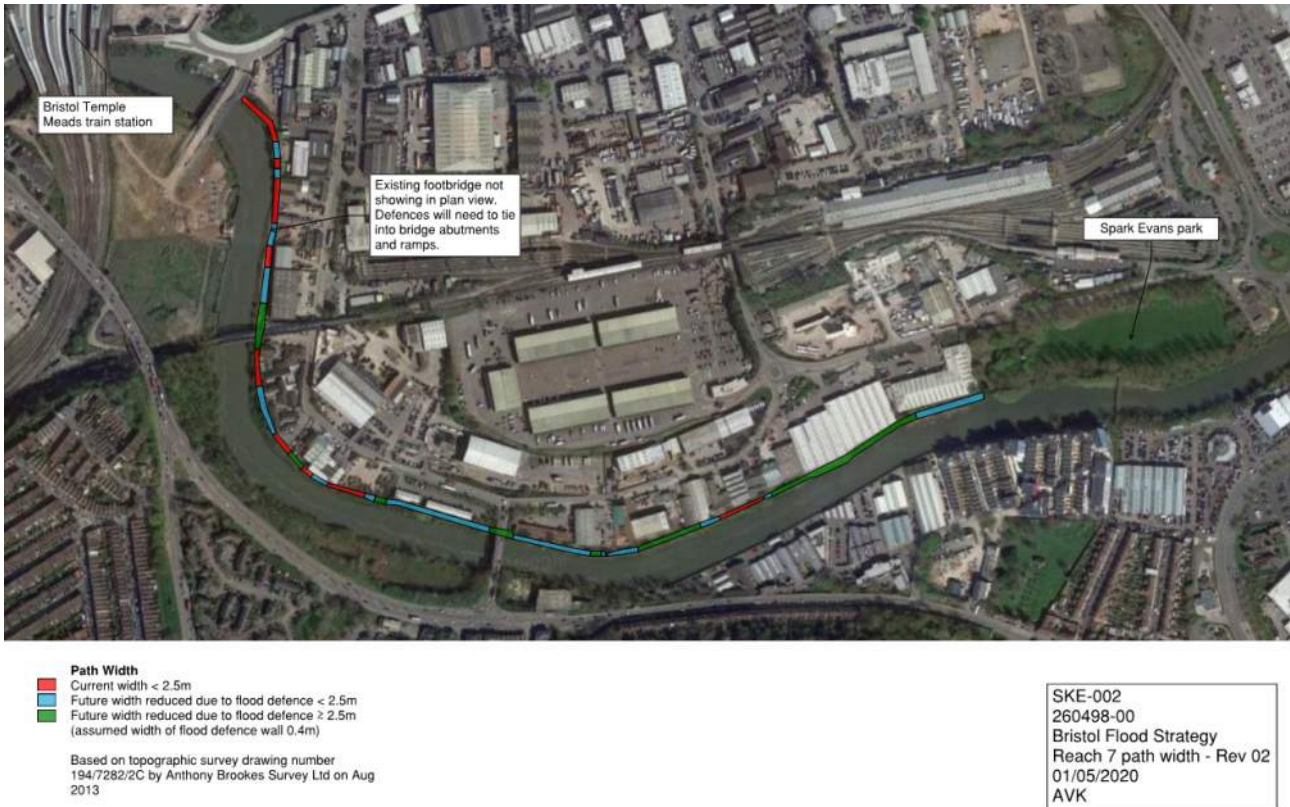


Figure 2 - Path width variation along Reach 7 section.

3.2 Constructability

Access to the St Philip's Marsh river path is relatively restricted and needs to be considered when deciding on the flood defence structure to be built. This is due to the sections with very limited path width, down to 1.5m, which would prevent large construction vehicles from travelling along the path. There are small piling rigs which would be suitable, although they may limit the size and type of piles that can be installed.

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Figure 3: Showing typical constrained section. Note comments are from AECOM's preferred option development report

The access and operational restrictions would favour solutions that minimise construction activities on-site, such as using pre-cast concrete sections over in-situ construction methods. Construction of the structure could be done using a jack-up vessel brought up the river, which would need to take into account the navigational clearance under the bridges over the River Avon and variation in draft due to the tidal river levels.

Approximate river bed levels decrease from 3m AOD (upstream end of St Philip's Marsh) to 1m AOD (half-way through the reach) and 0.5mAOD (downstream end)¹. The soffit of Temple Meads

¹ Levels from Arup flood modelling – combination of LiDAR and topographical surveys.

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bridge is at 10.7mAOD², and indicative tidal range levels vary from 2.8mAOD to 8.5mAOD³, meaning that clearance could be as low as 2.2m.

Alternatively, a floating barge could be assembled from land close to the site, for example from near Temple Island, and then used as a movable platform from which to construct the defence along the path.

In both cases, the use of vessels or barges would incur significant costs, much higher than construction on dry land only. They would also require authorisation form and coordination with the Harbour Master and may have a negative effect on the intertidal environment. There is a risk that the complexity and environmental impacts of this type of construction would not achieve planning consent.

3.3 Embankment stability

The stability of the embankment needs to be maintained both in the permanent case and also during construction. As described in Section 4, the top 10-12m of the ground in this area is made of weak alluvium soils, with a high risk of collapse during excavation if left unsupported.

The February 2015 GIR by CH2MHill noted that borehole results could suggest “historical slumping / slope instability of the river bank during placement of the Made Ground”. Furthermore, “the natural angle” of the bank may already be at or close to its critical angle for failure. There is potential that previous slope instability has occurred which may have resulted in the presence of existing planes of weakness where future slips could develop.” These risks will need to be further assessed in conjunction with piling contractors in later design stages and after updated geotechnical data is collected. A slope stability analysis will be required, informed by a bathymetric survey of the River Avon, and stabilisation measures may be necessary.

Once construction is complete, the risk of slope instability will be reduced if piles are used as they will generally be improving the ground at shallow depth (i.e. concrete instead of soft alluvium). However, the risk of shallow slip failures remains and will need to be addressed after reviewing data from an updated site-specific geotechnical investigation.

3.4 Existing structures

On the landward side of the path there are numerous existing structures, comprising mostly of boundary walls and warehouse or commercial buildings. The River Avon Heritage Assessment identified that the most significant heritage features in this area are the bridges and Sparke Evans Park, and notes that ‘inappropriate’ design would have a negative impact on these features. The majority of structures adjacent to the footpath are industrial units. The flood defences must tie in with any existing bridges.

At the point of carrying out this study, Arup does not have information on the foundations of the existing structures in St Philip’s Marsh. Given the geology of the area, where competent ground is found at a depth of approximately 10m, it is likely that buildings are founded on piles and would not increase the footprint of the structures beneath the ground surface. However, there is a

² Level from drawing no. MLS-10912-22 based on survey by Maltby Land Surveys Ltd on January 2010.

³ Indicative tidal range from a gauge in the river on the New Cut near Underfall Yard.

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possibility that the foundations could extend underneath the path and structural investigations would be required to address this risk in later stages of the project.

The flood defences should not rely on the integrity of existing structures and therefore a nominal gap is required between existing structures and new defence structures. Information on the condition of these buildings is limited, although by inspection most appear to be fairly old industrial warehouses. None were identified as being in a serious or critical condition in the asset condition surveys carried out by BCC. Any damage or disturbance to these structures could therefore result in compensation under the Water Resources Act, and therefore works will need to be designed and constructed to minimise the chances of a claim. A suitable method is discussed in 5.2.

3.5 Environmental

Environmental constraints and potential impacts of new structures are considered as part of the main project and are outside the scope of this technical note.

4 Ground Model

The central area of Bristol is characterised by a layer of weak alluvium superficial soils located where the river used to flow historically, as shown by the yellow area in Figure 4a. The competent bedrock layer is a mixture of Mercia mudstone and sandstones – shown in pink and brown in Figure 4b respectively.



Figure 4 - Geology in Bristol area with BTQ area marked in red, taken from British Geological Survey website. a) Superficial deposits b) Bedrock layer.

The ground model used in the analyses is summarised in Table 1, based on the Ground Investigation Report of Temple Quarter Enterprise Zone RIF St Philip’s Footbridge by CH2MHill on May 2016. The parameters were compared against the earlier data from the Draft ground Investigation Report of Bristol Harbour Walkway and Avon River Path by CH2MHill on February 2015. The results of both GIs are very similar and are captured in the ground model proposed.

It is worth noting that the superficial layers under the path are highly compressible and there is a risk the ground could consolidate under new structures. There are also pockets of soil with very poor geotechnical properties found within the layers that could collapse in open excavations. There is a known slip in the area considered. A bespoke ground investigation would be required to inform the detailed design of any required flood defences.

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Table 1 - Assumed ground conditions.

Layer	Thickness of layer ⁴ [m]	Unit weight, μ [kN/m ³]	Undrained shear strength, c_u [kPa]	Effective cohesion, c' [kPa]	Effective angle of friction, ϕ' [°]
Made Ground	4.9	20	0	0	25
Tidal Flat Deposits	6.1	19	10	0	25
River Terrace Deposits	1.3	20	0	0	32
Mudstone	-	23	200-250	20	32

5 Flood Defence Structures

5.1 Reinforced concrete retaining wall

A free-standing reinforced concrete L-shaped retaining wall would be relatively simple to install and would minimise disturbance to the existing structures on the landside. AECOM had previously proposed using existing structures along the Reach 7 as flood defences and building a free-standing concrete L-wall in any gaps between buildings. Following discussions with Bristol City Council, and as discussed in Section 3.4, Arup is proposing to build defence structures along the whole reach and not relying on any existing structures.

Based on the assumed ground conditions the bearing capacity of the superficial soil layers will be insufficient to support a free-standing wall placed on the surface. To resist the hydrostatic pressure from a flood event, the retaining wall would need to be buried approximately 2m below existing ground surface to mobilise sufficient passive pressure from the soil behind the wall. However, the excavations would require temporary support to ensure stability of the superficial soil layer. After exploring various options with piling contractor, we concluded that it was not practical in this constrained site and therefore discarded this option from further consideration.

5.2 Reinforced concrete wall founded on piles

A reinforced concrete L-wall supported on piles that are socketed into the competent bedrock layer will provide sufficient capacity to resist bearing failure. Overturning of the wall will be resisted by the piles acting in tension or compression as required. The sliding resistance will be provided by a threaded steel bar in the front pile, which will be installed at an angle. The structure will not rely on the superficial soil layers to provide resistance against loading.

The preliminary design for the proposed flood defence solution is appended at the end of this technical note. The resulting reduction in path width due to the proposed defence will be approximately 600mm, which would change the minimum path width from 1500mm down to 900mm. The proportion of the total 1500m of reach that would be under the recommended 2.5m width would change from the current 30% to over 70%.

⁴ Layer thicknesses are calculated using the averages based on the ranges stated in the report.

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As stated in Section 2, the preliminary design is based on the 2065 FCERM flood defence level. Preliminary calculations suggest that the reinforced concrete wall could be topped-up in the future to provide protection up to 2125 NPPF levels.

Arup held a meeting with Piling Foundation UK to discuss construction methods that would be suitable considering the site constraints. Drilled piles installed using an ODEX (Overburden Drilling EXcentric) system would be suitable for this scenario and has numerous benefits. The pile steel casing is installed as the drilling front moves down and provides stability through the superficial soil layers during piling. This method is capable of drilling through rock layers and could provide the required socket length into the bedrock. Piles could be installed using a restricted access drilling rig such as the Klemm 500 shown in Figure 5, which can work in widths down to 750mm.



Figure 5 - Klemm 500 piling rig, photo obtained from <https://www.klemm-bohrtechnik.de/1/products/drill-rigs/>, accessed on 12/03/2020.

The proposed method is a low vibration drilling technique which is environmentally sensitive to minimise disruption to existing structures. We also suggest monitoring the works with a vibration box that alerts if the particle velocity exceeds 5mm per second. BS5228-4 1992 sets a limit of 10mm per second so maintaining operations at this maximum particle velocity during drilling should minimise disruption to surroundings.

One of the benefits of using a rotary percussive drilling system such as ODEX is the small size and reduced weight of the rigs compared to other piling types. The width of the rig is typically about 1m to 2m, allowing it to fit in narrow areas, and the weight is of the order of 2 to 3 tonnes, therefore minimising the risk of slope instability during construction. Other piling rigs will be heavier and inherently pose a greater risk of slope instability.

A possible solution to reduce the risk of slope instability during construction would be to install the piles further away from the slope first, and then get the rig to sit on the installed piles during the installation of the edge piles. Piling from a barge may also be an option if proven that the slope is close to collapse, albeit more expensive. Other ideas from piling contractors can be reviewed and assessed once in later project stages.

In case of a local slope stability failure after the flood defence has been constructed, there shouldn't be any major impact on the structure, as the L-shaped concrete wall will be supported on piles socketed into the competent rock. However, it is recommended to investigate ways to protect the slope from shallow failures as part of the design in subsequent stages.

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6 Costs

Indicative costs for the proposed reinforced concrete wall supported on piles is provided in Table 2. The piling costs are based on the discussions with Foundation Piling UK and are for comparison purposes only. These costs do not form the basis of a quote.

Table 2 - Indicative costing for proposed defence wall.

Item	Cost	Assumptions
Pile material and installation	£4400/m	2 piles per metre of wall, 17m pile length with 1 threaded bar per pile.
Concrete wall	£1100/m	Arup costs for reinforced concrete wall of average width along path. Underpinning of existing wall is not included. No works are to be carried out to the embankment.
Sub-total	£5500/m	Excluding optimism bias.
Total	£8800/m	Costs include optimism bias of 60%.

7 Conclusions

This preliminary study on possible flood defence options for the footpath along Reach 7 has shown that:

1. A reinforced concrete wall supported by minipiles is a feasible solution. It would provide the required flood defence to 2065 FCERM levels with adequate structural and geotechnical stability and could be constructed taking into account the site constraints.
2. The reduction in path width based on the assumptions used for this study would be approximately 600mm, resulting in approximately 70% of the total 1500m that comprise the path in Reach 7 having a width smaller than 2.5m, compared with 30% currently.

There are various approaches available to compensate for the reduction in path width, and the solution can be developed further as part of the OBC.

- Cantilever a structure out from the wall to match existing width or to a minimum of 2.5m. This would incur an additional cost to the above. Preliminary calculations suggest that no additional piles will be needed to support the cantilever section. If required, piles could be installed after the wall section that sits on the path is constructed. The piling rig would be positioned on the wall slab and piles installed on the embankment edge closest to the path. The reach would be limited by the rig that could gain access via the path and subject to information from a GI and initial slope stability calcs. Consultation with a specialist contractor would be required.
- Compulsory purchase or acquire land by other means to enable the wall to be built landward. This option would present an opportunity to deliver alternative defence types, such as embankments or integrating into the developments. It would result in additional cost to the above.
- There may be opportunities for stretches of this defence to be developer-led, incorporating high ground, rather than purely providing flood defences.

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The risks, opportunities and indicative costs for comparative purposes between the different solutions are summarised in Table 3. The last 200m of reach 7 are located around Sparke Evans Park and are excluded from this cost comparison as the proposed defence is an earth embankment as proposed by AECOM.

Table 3 - Risk, opportunities and indicative costs for possible options.

Option	Risks	Opportunities	Indicative Cost ⁵
Piled wall with no cantilever (min path width approx. 0.9m)	<ul style="list-style-type: none"> Does not comply with Sustrans guidance in approx. 70% of path Additional compensation costs associated with damage to third-party structures 	<ul style="list-style-type: none"> Cantilever extension can be added in the future in phased approach 	£8800/m x 1300m = £11.4mill
Piled wall with cantilever to match existing path width	<ul style="list-style-type: none"> Does not comply with Sustrans guidance in approx. 30% of path May impact intertidal habitats on river banks if present Additional compensation costs associated with damage to third-party structures 	<ul style="list-style-type: none"> Cantilever extension can be added in the future in phased approach 	£8800/m x 1.15 x 1300m = £13.2mill ⁶
Piled wall with cantilever to get min. path width of 2.5m	<ul style="list-style-type: none"> May impact intertidal habitats on river banks if present Additional compensation costs associated with damage to third-party structures 	<ul style="list-style-type: none"> Complying with Sustrans minimum path width may increase value of future development in the area 	£8800/m x 1.25 x 1300m = £14.3mill ⁶
Piled wall with cantilever to get recommended path width of 3.0m	<ul style="list-style-type: none"> May impact intertidal habitats on river banks if present Additional compensation costs associated with damage to third-party structures 	<ul style="list-style-type: none"> Complying with Sustrans recommended path width may increase value of future development in the area 	£8800/m x 1.5 x 1300m = £17.2mill ⁶
Piled wall with land purchase in sections where path width is less than 2.5m	<ul style="list-style-type: none"> Negotiations about land purchase may delay scheme Additional compensation costs associated with 	<ul style="list-style-type: none"> Complying with Sustrans recommended path width may increase value of future development in the area 	(£8800/m x 1300m) + (£800/m ² x 2.5m x 0.7 x 1500m) = £13.5mill ⁷

⁵ Costs include optimism bias of 60%.

⁶ Indicative cost for cantilever extension options is based on additional reinforced concrete material required only. Additional costs from piling operations are excluded as it is assumed at this stage that no additional piles will be required.

⁷ Assumed cost of land purchase £500/m², an indicative value suggested by BCC for industrial land with reasonable possibility of residential consent in next 5-10 years, plus 60% to account for optimism bias.



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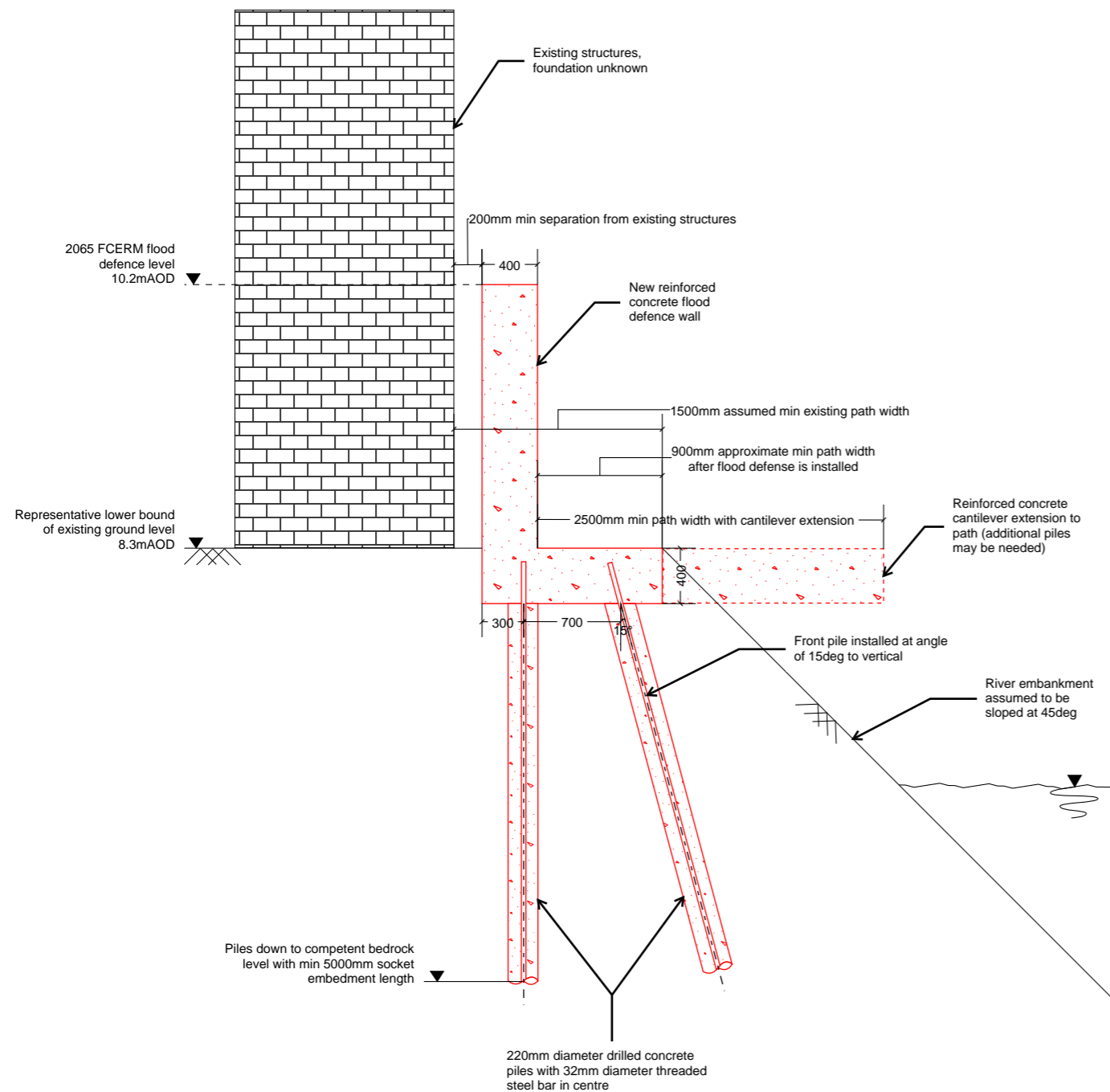
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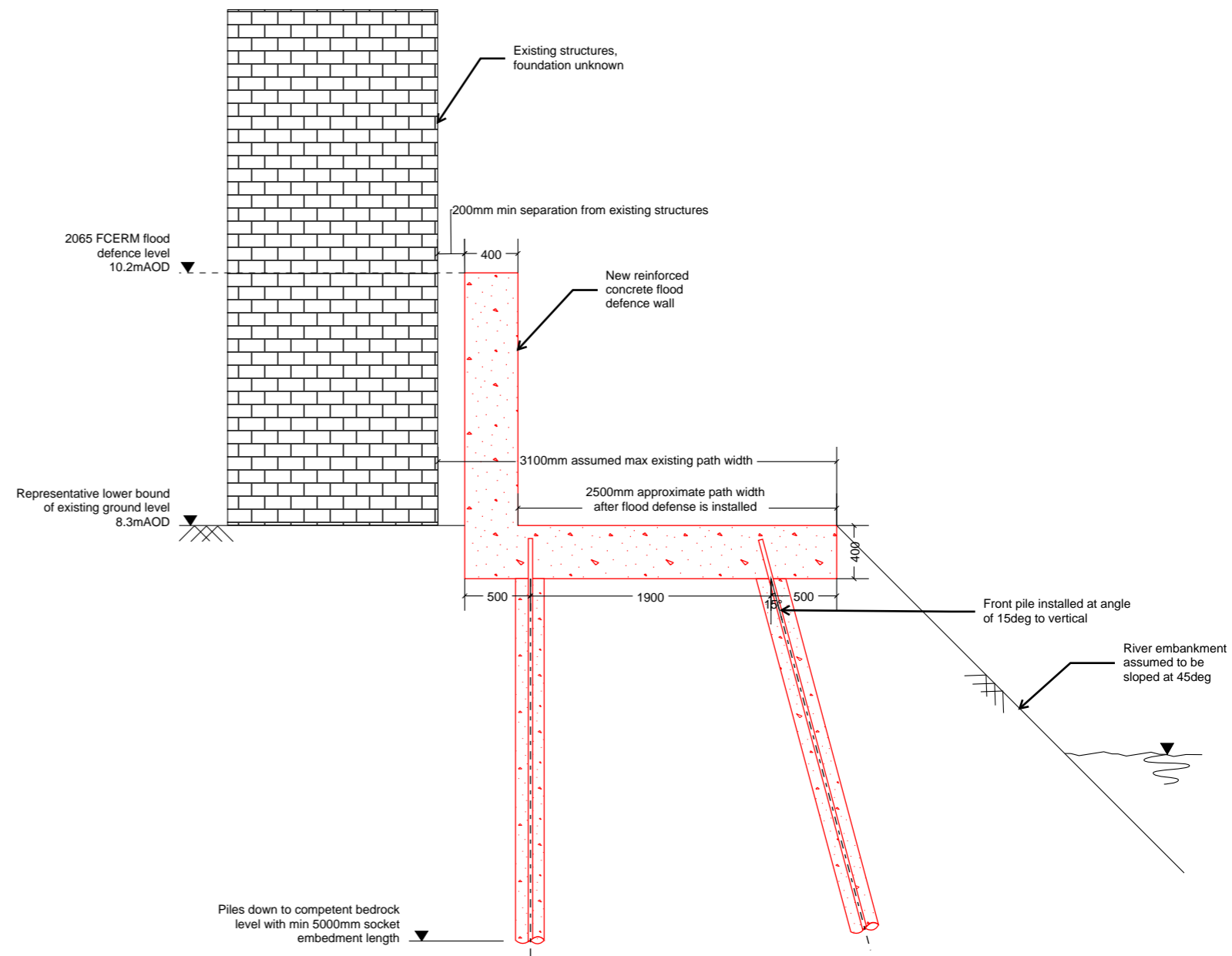
	<p>damage to third-party structures</p> <ul style="list-style-type: none"> • Additional costs associated with compensation and legal agreements 		
<p>Land purchase for placemaking proposal for new development in the BTQ area (20m from edge of path to development) with embankment defence</p>	<ul style="list-style-type: none"> • Negotiations about land purchase may delay scheme • Additional compensation costs associated with damage to third-party structures • Additional costs associated with compensation and legal agreements 	<ul style="list-style-type: none"> • Realise the full benefits of the placemaking proposal • Consider alternative defence types such as embankments or integrating into developments 	<p>(£2816/m x 1300m) + (£800/m² x 18m x 1300m) = £18.8mill⁷</p>

DOCUMENT CHECKING (not mandatory for File Note)

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REACH 7 - NEW FLOOD RETAINING WALL SECTION (2065 FCERM LEVEL AND MIN INDICATIVE PATH WIDTH)



REACH 7 - NEW FLOOD RETAINING WALL SECTION (2065 FCERM LEVEL AND MAX INDICATIVE PATH WIDTH)

ARUP			
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