AECOM

RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY

Optimised phasing of the preferred Strategy option

Economic Appraisal Update

April 2017

Prepared for Bristol City Council

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1 INTRODUCTION

1.1 Overview and purpose of this report

As part of the development of the River Avon Tidal Flood Risk Management Strategy ('The Strategy') AECOM has carried out an economic appraisal. This appraisal includes a valuation of the potential damage that could result from tidal flood risk as a result of a 'Do Nothing' scenario and the benefits that could be obtained by a 'Do Something' option. The previous phase of work examined a number of potential 'Do Something' Options and quantified the benefits associated with each in order to allow them to be directly comparable and hence identify a preferred flood defence option. Further details on this study and the methodology used can be found in the 'Economic Appraisal – Briefing Report' as part of the River Avon Tidal Flood Risk Management Strategy which covers the preceding stages of this study.

This stage of the works builds upon these previous findings which were presented to Bristol City Council (BCC) and aims to provide a more detailed assessment of the preferred option and how it will be implemented over the Strategy appraisal period.

This briefing report presents the outcomes from this further study. One of the key elements examined as part of this updated phase of works involves quantifying the benefits associated with the phasing of the chosen option. This work therefore forms a key part of the Strategy and will help to inform the development of a business case for a preferred management option.

2 DEFENCE PHASING

2.1 Background

The preferred strategic option which was identified in the previous phase of work was to construct low defences in the first epoch of the Strategy (present day to 2030) and then raise the defences to high defences in the final epoch of the Strategy (from 2065 to 2115). In the interim between these time periods the low defences would be maintained. **Table 2-1** provides a summary of the standard of protection provided by the preferred option over the next 100 years (based on FCERM recommended Climate Change allowances).

Table 2-1 Standard of protection provided by the preferred option

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

Additional work has been carried out to investigate how the low defences could be more optimally phased over the course of the first two time epochs. The onset of flood risk varies along the Strategy frontage and there could be merit in delaying the construction of some low defence schemes until the second epoch (between 2030 and 2065). The onset of risk in some areas may not be fully established until epoch 2 and constructing defences in these areas prior to this may not be an optimal approach. In addition, delaying certain schemes may provide opportunities to align the defences with other works to structures and assets in the study area.

Another key benefit of phasing the implementation of low defences is that it helps spread the capital investment over a longer time period meaning reduced present value costs for the Strategy. Delaying certain low defence schemes until epoch 2 also provides BCC with greater time to make up potential funding shortfalls, acquire contributions or to redirect funds to flood defence schemes. In addition, phasing also helps to reduce delivery risks by reducing the size of design and construction contracts.

Investigating and improving the phasing of low defences also ensures that investment is made on a risk based approach (only implementing defences as required) and that the Strategy is more adaptive to climate change. Delayed low defence schemes which are not required immediately can be implemented as and when required in the future depending on the rate of climate change and sea level rise.

The project team held a prioritisation and phasing workshop (5th October 2016) and discussed the onset of flood risk across the Strategy frontage. From this meeting initial ideas were gathered as to which low defence schemes could be delayed until epoch 2. Follow up work was then undertaken to split the flooding across the Strategy area into distinct flood cells. This allowed the economic flood damages and benefits of schemes in each flood cell to be derived and the phasing of low defences to be verified.

2.2 Flood cells

During larger return period events the flood extent in central Bristol comprises a large flood cell surrounding the Floating Harbour and the areas adjacent to the New Cut. By examining animations of modelled flood events and inspecting how the flood cell propagates it has been possible to sub-divide the flood cell. The following sub-cells were identified:

Floating Harbour;

Cumberland Road;

Commercial Road;

Clarence Road;

Cattle Market Road; and

Totterdown / St. Phillips

The sub-cells are separate from each other during smaller magnitude events, but as the flood risk develops the cells merge in various locations. Based upon the existing modelling it is not possible to determine the volumes of water that flow between sub-cells. As such, the sub-cell boundaries are arbitrary and are limited by the modelling capabilities. Further modelling would be required to identify the volume of water that passes between flood cells and to verify the boundaries.

The boundaries of the sub-cells that are protected by the high defences during a 2115 200yr tidal event are shown in Figure 2-1. During this magnitude event the sub-cells have merged in various locations, for example between Cumberland Road and the Floating Harbour, and between Totterdown and the Floating Harbour. For events of even larger magnitude the extent of the flood cells will increase in size and depth.

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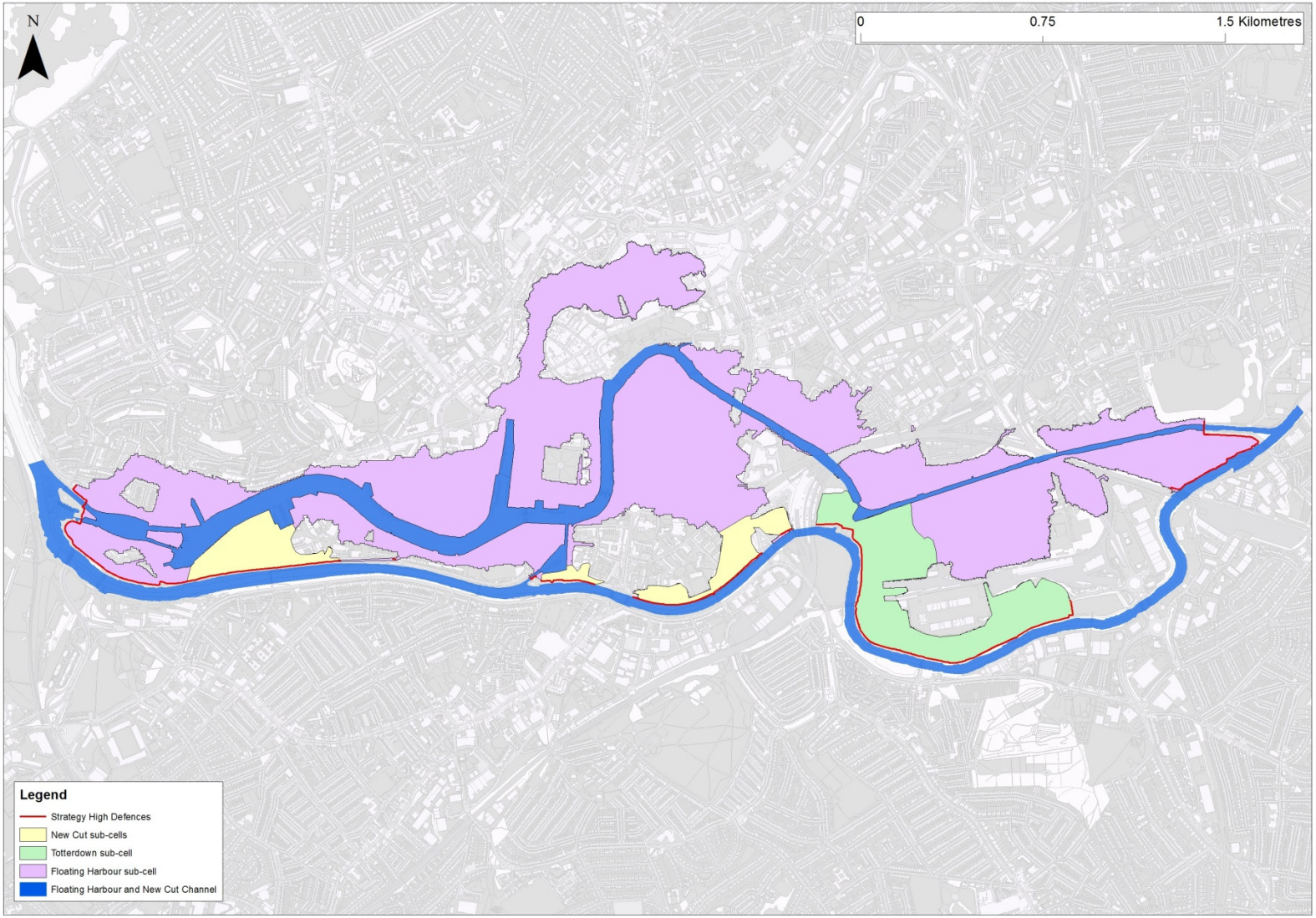

Figure 2-1 Sub-cells (benefit areas) during a 1:200 year event for the Floating Harbour, New Cut and Totterdown. The sub-cells are only shown for the areas behind the proposed defences which will be protected

Table 2-2 below shows the numbers of properties at risk from 1:20, 1:75 and 1:200 year flood events within each flood cell. The equivalent data showing the percentage of properties at risk by flood cell (within central Bristol) is shown in Table 2-3. The tables demonstrate how flood risk propagates across the city in relation to the number of properties at risk.

Table 2-2. Numbers of properties at risk in each flood cell (Do Nothing scenario), by year and return period event

Flood cell	2015			2030			2065			2115		
	20yr	75yr	200 yr	20yr	75yr	200yr	20yr	75yr	200yr	20yr	75yr	200 yr
Floating Harbour	913	1317	1891	1064	1375	2056	1376	1870	2540	2074	2364	2970
New Cut	97	116	155	111	145	173	148	159	200	176	199	229
Totterdown / St. Phllips	88	103	173	112	145	178	145	171	192	177	190	194

Table 2-3. Percentage of total properties at risk by flood cell location (Do Nothing scenario), by year and return period event

Flood cell	2015			2030			2065			2115		
	20yr	75yr	200 yr	20yr	20yr	75yr	200 yr	20yr	20yr	75yr	200 yr	20yr
Floating Harbour	83%	86%	85%	82%	82%	86%	82%	85%	87%	86%	86%	88%
New Cut	9%	8%	7%	9%	9%	7%	9%	7%	7%	7%	7%	6%
Totterdown / St. Phllips	8%	6%	8%	9%	9%	7%	9%	8%	6%	7%	7%	6%

Table 2-3 shows that the majority of properties at risk within the first time epoch are found within the Floating Harbour (83-86%). The flood cells at the New Cut and Totterdown / St. Phillips have comparatively fewer properties at risk within the first time epoch, with 7-9% and 6-8% respectively.

In the second time epoch (from 2030 to 2065) the flood cells at the New Cut and Totterdown / St. Phillips have an increased number of properties at risk, but as a percentage these flood cells occupy a similar proportion of risk as in epoch 1, given that the number of properties at risk has also increased in the Floating Harbour cell.

2.3 Phasing plan

2.3.1 *Defence phasing*

The project team devised a phasing plan for the preferred strategic option based upon the team's understanding of the onset of flood risk, the numbers of properties at risk in each flood cell, deliverability and securing the maximal return on investment. For more details on the phasing plan and how it was developed refer to the Preferred Options Development Report.

The Floating Harbour sub-cell has the greatest number of properties at risk within epoch 1 and therefore defences for this cell are a priority. The defences for the Floating Harbour include the defences at

Entrance Lock, Cumberland Road underpass, Bathurst Basin Dam and Netham. For the Floating Harbour defences to be at their most effective it requires defences to be constructed at all four locations. This will ensure that the major routes for flood water into the harbour are blocked during potential flood events. If defences are not constructed in one or more of the locations then flood water will still be able to flow into the harbour, albeit at a reduced rate. The Floating Harbour has some storage capacity for flood water but it is limited and if one or more of the defences are not constructed then there is a chance that the storage capacity will be exceeded and flooding could occur within central Bristol.

Defences are also a priority at Totterdown / St. Phillips. The initial flood risk in this area is not as prominent as in the Floating Harbour (in terms of property numbers), but during larger magnitude events the flood modelling suggests that water flows from the Totterdown sub-cell into the Floating Harbour. Therefore in order to fully realise the benefits of the Floating Harbour schemes it will be necessary to construct the Totterdown defences. In addition, the Totterdown / St.Phillips area is currently being redeveloped as part of the Arena development and there are works planned to raise the path either side of the new footbridge. This offers an excellent opportunity to utilise these improvements as part of a low defence scheme during epoch 1 of the Strategy.

During epoch 1 the flood risk is relatively low at Cumberland Road, Commercial Road, Clarence Road and Cattle Market road (i.e. the New Cut areas) and there are relatively fewer properties at risk compared to the Floating Harbour. For this reason, defences in these areas are less of a priority and could feasibly be delayed until epoch 2 of the Strategy.

Similar to the example at Totterdown, during large magnitude events the New Cut sub-cells appear to merge with the Floating Harbour in various locations. However, inspection of the modelling results suggests that the extent to which the flood cells merge is less than at Totterdown and it only occurs from larger magnitude events (for example Totterdown merging occurs from a present day 1:20 year event, whilst Commercial Road merging occurs from a present day 1:75yr event). During further design development it is recommended that additional modelling is undertaken to investigate the extent and volumes of water flowing between the New Cut and Floating Harbour sub-cells.

The phasing plan for the preferred option is as follows:

Epoch 1 (from present day to 2030)

- Construct low defences to the Floating Harbour flood cell at Entrance Lock, Cumberland Road underpass, Bathurst Basin Dam and Netham (Floating Harbour defence group).
- As an exception, the new lock gates at Entrance Lock and Netham will have a crest level for high defences (to avoid having to go back in 2065 and providing a new set of gates). For the rest of the scheme's length the defences will be constructed to the low defence height.
- Low defences at Totterdown / St. Phillips.

Epoch 2 (from 2030 to 2065)

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

Epoch 3 (from 2065 to 2115)

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

Figure 2-2 shows the phasing plan for the low defence schemes.

2.3.2 *Assumptions for the phasing plan and derivation of flood cells*

During the lowest return period events the numerical modelling suggests that the New Cut, Totterdown and Floating Harbour sub-cells are separate and flood water does not flow from one cell to another. However this is not the case during larger magnitude events when the Totterdown and New Cut sub-cells appear to merge with the Floating Harbour. With the current modelling it is not possible to accurately determine the flow pathways or the volumes of water involved.

For the purpose of developing the economic assessment in line with the phasing plan it has been necessary to assume that the benefits of the schemes are obtained from the sub-cells directly protected by the defences. This assumption was required in order to sub-divide the defence benefits.

This assumption is considered to be reasonable because the majority of the economic benefits of the defences are driven by the lower return period events and the uncertainty associated with the merging of sub-cells during higher return period events is unlikely to significantly influence the economic assessment.

In addition, for the majority of flood events if flow pathways exist between sub-cells then the volume of water flowing into the Floating Harbour is likely to be small in comparison to the large entry points elsewhere (i.e. at Entrance Lock).

Additional modelling is required to investigate flow pathways between the sub-cells in more detail and to determine the volumes of water involved. This information would help to verify the assumptions made in developing the economic assessment.

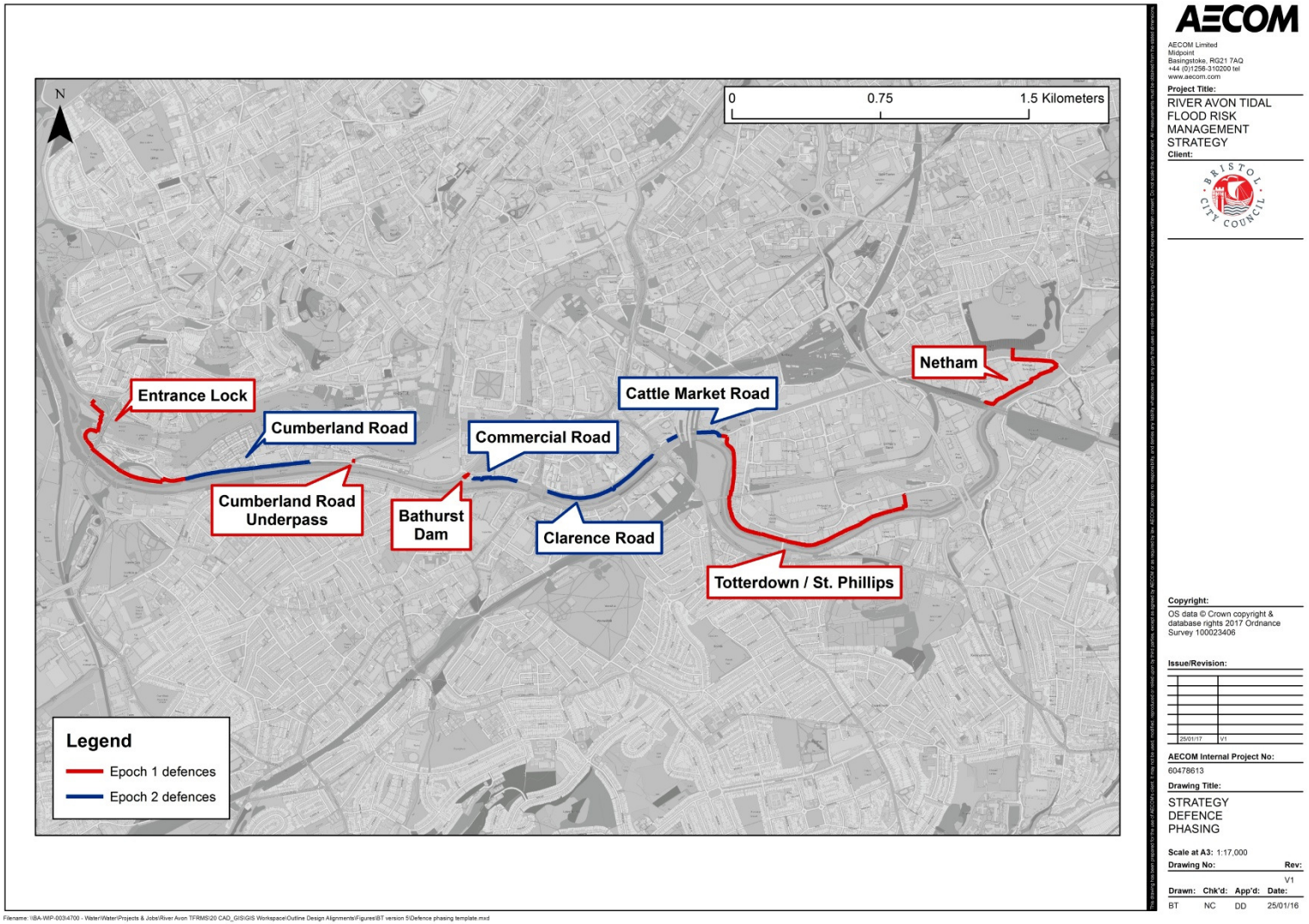

Figure 2-2 Low defence phasing

3 ECONOMIC APPRAISAL OF UPDATED PREFERRED OPTION

3.1 Phasing economic benefits

The economic benefits of the preferred option have been updated to account for the phased delivery of schemes. The economic benefits of the preferred option with the updated phasing are presented in **Table 3-1** below. The benefits are shown in present value (PV) terms for the full Strategy appraisal period (next 100 years).

The economic benefits of the preferred option include the benefits from Doing Minimum. This is because the Do Minimum activities (such as the operation of the Floating Harbour water level controls) will be carried out alongside construction of the new raised defences.

Table 3-1 Present value Do Nothing Damages and benefits expected for each of the epochs for the preferred option with phasing

Do Nothing damages (£k)	*PV 'flood risk' benefits (£k)	PV 'other' benefits (£k)	PV total benefits (£k)	Residual damages (£k)
1,630,882	1,509,827	26,330	1,536,157	94,725

*note: phased option benefits include benefits from Do Minimum

Table 3-2 compares the economic benefits of the original preferred option (last stage of work) to the phased preferred option. Compared to the preferred option benefits derived during the last stage of work the benefits have reduced by approximately £40m over the lifetime of the scheme. There are two reasons for this. Firstly, the preferred option benefits derived during the last stage of work include benefits at Pill and Shirehampton whilst the updated benefits do not. Secondly, the updated defence phasing results in a number of low defence schemes being delayed to epoch 2. In areas where schemed are delated the baseline flood damages for epoch 1 are expected to occur which reduced the whole life benefits of the phased preferred option.

Table 3-2 Comparison of pre-phased and phased preferred options benefits

Option	PV total (£k) Epoch 1	PV total (£k) Epoch 2	PV total (£k)
Original preferred option*	1,557,810	1,558,042	1,575,932
Phased preferred option	1,411,023	1,462,295	1,536,157

*includes benefits for Pill and Shirehampton schemes

3.2 Cost updates

3.2.1 *Capital costs*

Capital costs refer to the upfront costs of a scheme, including costs for the appraisal, procurement, design and construction. Capital costs do not include maintenance costs.

The capital costs for the preferred option schemes have been updated during this phase of work. Refer to the Outline Design report and appendices for a breakdown of the costing approach and an overview of the rates which have been used.

A summary breakdown of the capital costs for the preferred option is provided in Table 3-3. A 60% optimism bias has been applied to all capital construction costs. A summary breakdown for the Floating Harbour, Totterdown and New Cut schemes is provided separately in Table 3-4 to Table 3-6.

The capital costs for the low defences are typically higher than for the high defences. This is because construction of high defences will generally involve raising the crest level of the existing low defences and there will not be a need for new foundations. The exceptions to this are at Cumberland Road and Totterdown where construction of high defences will require completely new lengths of defence.

Additional lump sums for construction and 'other' costs have been included in the overall cost estimate. The lump sum costs have been broken down for the individual schemes by distributing the costs across each defence area in a weighted manner according to the proportions between the scheme and total costs and when schemes are being undertaken.

The additional lump sum costs for construction includes allowances for service diversions, dealing with existing surface water outfalls, back of wall drainage and landscaping and public realm works.

The additional lump sum costs for 'other' includes allowances for Environmental mitigation for 'coastal squeeze' (compensatory habitat), other environmental mitigation, investigations (e.g. ground surveys, topographic surveys, services etc.), developing the business case and detailed design, compensation and compulsory purchase.

The costs also include an estimate for mitigating potential detriment from the Strategy. The detriment costs have been broken down for the individual schemes by distributing the costs in a weighted manner according to the proportions between the scheme and total costs. Detriment costs have been apportioned to the Floating Harbour and Totterdown schemes as according to the defence phasing plan these schemes are scheduled to occur first. It has been assumed that planning consents for the low and high defence schemes will only be granted if the suitable detriment mitigation is in place.

Table 3-3. Updated capital construction costs for the preferred option schemes (including 60% optimism bias)

Scheme	Defence / benefit area	Low Defences Capital cost (£k)	High Defences Capital cost (£k)
Entrance Lock	Floating Harbour	14,020	4,870
Cumberland Road	New Cut	2,190	8,220
Cumberland Road underpass	Floating Harbour	410	190
Bathurst Dam	Floating Harbour	230	50
Commercial Road	New Cut	2,130	640
Clarence Road	New Cut	4,870	1,350
Cattle Market Road	New Cut	1,380	370
Totterdown / St. Phillips	New Cut	5,570	7,550
Netham	Floating Harbour	10,610	6,830

Detriment mitigation	4,190	1,530
Additional costs – lump sums construction	5,500	3,430
Additional costs – lump sums other*	10,220	9,200
Sub - total	**61,330**	**44,240**
Total (£k)	**105,570**	

*60% optimism bias not applied to 'lump sums other' costs

Table 3-4 Updated capital costs for the Floating Harbour scheme (including 60% optimism bias)

Scheme	Defence / benefit area	Low Defences Capital cost (£k)	High Defences Capital cost (£k)
Entrance Lock	Floating Harbour	14,020	4,870
Cumberland Road underpass	Floating Harbour	410	190
Bathurst Dam	Floating Harbour	230	50
Netham	Floating Harbour	10,610	6,830
Detriment mitigation		3,350	1,220
Additional costs – lump sums construction		2,200	1,370
Additional costs – lump sums other*		4,090	3,680
Sub - total		**34,910**	**18,210**
Total (£k)		**53,120**	

*60% optimism bias not applied to 'lump sums other' costs

Table 3-5 Updated capital costs for the Totterdown scheme (including 60% optimism bias)

Scheme	Defence / benefit area	Low Defences Capital cost (£k)	High Defences Capital cost (£k)
Totterdown / St. Phillips	Totterdown	5,570	7,550
Detriment mitigation		840	310
Additional costs – lump sums construction		550	340
Additional costs – lump sums other*		1,020	920
Sub - total		**7,980**	**9,120**
Total (£k)		**17,100**	

*60% optimism bias not applied to 'lump sums other' costs

Table 3-6 Updated capital costs for the New Cut scheme (including 60% optimism bias)

Scheme	Defence / benefit area	Low Defences Capital cost (£k)	High Defences Capital cost (£k)
Cumberland Road	New Cut	2,190	8,220
Commercial Road	New Cut	2,130	640
Clarence Road	New Cut	4,870	1,350
Cattle Market Road	New Cut	1,380	370
Additional costs – lump sums construction		2,750	1,720
Additional costs – lump sums other*		5,110	4,600
Sub - total		**18,430**	**16,900**
Total (£k)		**35,330**	

*60% optimism bias not applied to 'lump sums other' costs

3.2.2 *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

The cost build up for each aspect of maintenance is provided in Table 3-7 below.

Table 3-7 Maintenance cost build up

Source	Aspect	Cost (£k)	Frequency
EA guidance for estimating maintenance costs of raised defences	Maintenance of low defences (2015-2030)	7.9	Yearly
	Maintenance of low defences (2030-2065)	9.2	Yearly
	Maintenance of high defences (2065-2115)	8.9	Yearly
EA SAMP costs	Maintenance of existing raised defences, structures and asset operation and incident response	35.1	Yearly
Cathodic protection (sheet pile structures only)	Cathodic protection for low defences	1,872.0	Assumed it will be required every 20 years
	Cathodic protection for high defences	1,915.0	Assumed it will be required every 20 years

Estimates of the total maintenance costs vary according to the time period and schemes in place (i.e. low defences or high defences). For each time epoch in the preferred option an annual maintenance cost has been estimated by adding the annual maintenance cost obtained from the EA guidance to the EA SAMP costs. For example, for low defences between 2015 and 2030 the annual maintenance cost has been estimated to be £7.9k + £35.1k = £43k.

In addition to the annual maintenance cost, the cost for providing cathodic protection to the sheet pile structures was applied every 20 years. The cost of cathodic protection was not annualised, but was applied as a recurring lump sum in the present value costing sheets (every 20 years).

3.2.3 *Harbour operation and maintenance costs (flood risk protection only)*

The costs and frequency of the various factors involved in operating the Floating Harbour were provided by BCC. From this the harbour costs associated with providing a flood defence function were used to derive a total annual operation cost of the harbour (in terms of flood risk reduction). Table 3-8 provides a breakdown of the estimated annual operation costs for the present day.

Table 3-8 Present day harbour operations cost build up

Action	**Estimated annual cost (£k)**
Pre event incident planning / coordination	2.1
Deployment of stop gates at Junction Lock / Netham	23.9
Pre event harbour lowering	0.2
Various inspections of stop gate pair	10.2
Total	**36.4**

Due to sea level rise the frequency of harbour operations and gate deployment is expected to increase in the future and therefore an uplift was applied to estimate the costs in 2030, 2065 and 2115. Table 3-9 shows the estimated harbour operations costs for the strategy time epochs.

Table 3-9 Annual harbour operations costs for different time epochs in the Strategy

Strategy time period	**Estimated annual cost (£k)**
2015 (present day)	36.4
2030	37.5
2065	55.9
2115	135.3

In addition to the annual operation costs, a cost of £174k associated with maintenance of the stop gates was assumed to occur every 25 years. This cost was provided by BCC as part of the harbour operations costs. This cost was not annualised, but was applied as a recurring lump sum in the present value costing sheets (every 25 years).

3.2.4 *Do Minimum costs*

The cost of the Do Minimum scenario has been updated so that the incremental benefit cost ratio of the preferred option can be identified.

The Do Minimum costs include the costs of harbour operation (see section 3.2.3), maintenance costs for the existing BCC raised defences (at Totterdown and the MetroBus flood wall) and the EA SAMP costs.

The maintenance costs for the existing BCC raised defences (Totterdown / MetroBus) have been estimated using the EA guidance document for estimating maintenance costs for raised defences.

A breakdown of the Do Minimum costs is provided in Table 3-10.

Table 3-10 Do Minimum cost breakdown

Source	Aspect	Cost (£k)	Frequency
Harbour operations costs	Operations cost (2015 – present day)	36.4	Yearly
	Operations cost (2030)	37.5	Yearly
	Operations cost (2065)	55.9	Yearly
	Operations cost (2115)	135.3	Yearly
	Maintenance of stop gates	174.0	Assumed every 25 years
Existing raised defences	Totterdown embankment and MetroBus flood wall	1.4	Yearly
EA SAMP costs	Maintenance of existing raised defences, structures and asset operation and incident response	35.1	Yearly

3.2.5 *Present value costs*

The whole life present value cost for the preferred option has been updated to reflect the changes to the option phasing and the updated capital cost estimates.

Present value costs include discounting and enable the whole life cost of an option to be established in today's cost terms. Standard discount rates have been used to convert the non-discounted cash cost of the phased preferred option to a present value cost. According to the FCERM-AG, the following variable discount rates have been used; 3.5% for the years 0 to 35, 3.0% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A cost profile for the phased preferred option is presented in Table 3-11 below. The cost profile has been produced by applying the discount factor to the capital cost of the various schemes for the year in which they are to be implemented. For the purpose of discounting it has been assumed that schemes will be implemented in the first year of the time epoch for which they are scheduled. For instance, with the updated phasing, the low defences at Entrance Lock, Cumberland Road underpass, Bathurst Dam, Netham and Totterdown / St.Phillips are scheduled for epoch 1 and it has been assumed that these schemes will be constructed now. Low defences at Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road are scheduled for epoch 2 and it has been assumed that these schemes will be constructed in 2030.

Maintenance costs and costs associated with sustaining operation of the floating harbour include an annual average cost for the duration of the appraisal period which has been discounted on a yearly basis. Recurring lump sum costs for maintenance and operation have also been included in the PV cost sheet. In Table 3-11 maintenance costs refer to the costs associated with maintaining defences whilst 'other' costs are those costs associated with Floating Harbour operation and maintenance that is specific

to managing the flood risk (i.e. deployment and upkeep of stop gates). The average annual cash cost for these activities differs between time epochs due the implementation of schemes.

For detriment mitigation costs it has been assumed that the full cost for the works to mitigate the impact of low defences will occur at the start of epoch 1. This is because it is recommended that the detriment mitigation is carried out at the time of constructing low defences. For the detriment mitigation costs for high defences it has been assumed that the costs will occur in 2065, at the start of epoch 3.

The cost profile is shown in Table 3-11. The total present value cost of the phased preferred option is estimated to be approximately £79.1 million. In present value terms the majority of the investment is required in epochs 1 and 2, when the construction of low defences is scheduled. In epoch 3, despite there being a large non discounted cash investment required to upgrade to high defences, the larger discount rate ensures that the present value cost in this epoch is comparatively smaller.

Table 3-11. Cost profile of non-discounted (cash) and present value (PV) costs for the phased preferred option

Epoch	Non discounted (cash) cost (£k) including 60% optimism bias				Present value cost (£k) including 60% optimism bias			
	Capital	Maintenance	Other*	Total	Capital	Maintenance	Other*	Total
Epoch 1	42,900	650	550	44,090	42,900	510	430	43,840
Epoch 2	18,440	5,290	1,490	25,220	11,000	1,990	550	13,540
Epoch 3	44,240	6,030	5,130	55,400	8,730	680	490	9,890
			Total	124,700			**Total**	67,280

Updates to the capital costs and defence phasing have reduced the whole life present value cost of the preferred option compared to the estimate made in the previous phase of work (during the preferred options phase). Whole life non discounted (cash) costs have reduced from £304.2million to £124.7 million and total present value costs have reduced from £166.3million to £67.3 million.

There are two key reasons for the reduction in whole life non-discounted (cash) costs of approximately £179 million since the preferred options stage. Firstly, during the preferred options stage the costing was based on an overly precautious approach. It was assumed that all defences within the Strategy area would be a frontline piled solution which was the most costly structure type considered. During this phase of work more detailed investigations have been undertaken to improve confidence that setback solutions are technically viable and the lower overall non-discounted (cash) cost of the option reflects this. Secondly, the non-discounted (cash) cost presented during the preferred options stage includes costs for defences at Pill and Shirehampton. During this phase of work it was agreed with BCC to exclude these schemes as they are separate schemes in their own right and this phase of work is focussed on central Bristol. During the preferred options stage the total cost estimate for the low defences and high defence upgrade at Pill and Shirehampton was approximately £30 million. This represents approximately 17% of the £179 million cost reduction since the preferred options stage.

The whole life PV cost of the preferred option has also significantly reduced. This is partly due to a reduction in the non-discounted (cash) cost of the option but changes to the phasing of the option has also contributed. By delaying the construction of low defences at Cumberland Road, Clarence Road, Commercial Road, Cattle Market Road and Totterdown / St.Phillips it has resulted in a greater discount factor being applied to these schemes which has helped to reduce the overall PV cost.

3.3 Benefit : Cost Ratio

The economic costs and benefits of the phased preferred option have been updated during this phase of work and the average benefit cost ratio (ABCR) has been recalculated.

The ABCR is the calculation whereby the benefits generated by the option are divided by the cost of implementing the option. The ABCR provides a basic marker as to whether an option is economically viable. If the ABCR is >1, it demonstrates that the option benefits outweigh the option costs.

A comparison of the ABCR values for both the phased and non-phased approach to Strategy implementation is included in Table 3-12 below.

Table 3-12. ABCR for the phased and non-phased preferred option

Option	Notes	PV costs (£m)	PV benefits (£m)	ABCR
Preferred option prior to updates (last phase of work)*	Original capital cost estimates and phasing (all low defences in epoch 1)	166.3	1,575.9	9:1
Preferred option following updates	Updated capital cost estimates and phasing (New Cut low defences delayed until epoch 2)	67.3	1,536	23:1

Table 3-12 demonstrates that the ABCR of the preferred option has significantly increased following the introduction of phasing, rising from 9:1 to 23:1. Whilst the PV benefits of the option have reduced, the PV costs have decreased by almost a half, falling from £166.3m to £67.3m.

3.4 Incremental Benefit Cost ratio

During the last phase of work, the Incremental Benefit Cost Ratio (IBCR) of the options was calculated to determine whether there was a case for additional investment to improve the standard of protection. The IBCR of the preferred option prior to the updates which have been discussed in this report was calculated as approximately 1.8 relative to Do Minimum. As part of this stage of work the IBCR of the revised option has been calculated and is presented in **Table 3-13.** below. In order to update the IBCR, the costs of the Do Minimum scenario have also been updated. The basis for the updates to the Do Minimum cost is discussed in section 3.2.4.

Table 3-13. IBCR assessment

Option	PV costs (£m)	PV benefits (£m)	ABCR	IBCR
Do Nothing	0	0	0	/
Do Minimum	2.6	1,309	503 : 1	503
Preferred option (following updates)	67.3	1,536	23 : 1	3.5

Do Minimum and preferred option costs and benefits do not include Pill and Shirehampton

The IBCR of the preferred option relative to the Do Minimum is approximately 3.5. This represents a significant increase in the IBCR compared to the ratio which was calculated during the last phase of work (ratio of 1.8). The increase in the IBCR is down to reduced PV costs of the preferred option as a result of the revised capital costs and phasing.

An IBCR greater than 1 represents a worthwhile return on additional investment. According to FCERM-AG, to justify an increase in the standard of protection from a 1:75 year standard to a 1:200 year standard it is necessary to have an IBCR of greater than 3. The revised IBCR of 3.5 for the preferred

option falls above this threshold. However, the IBCR threshold of >3 only applies if there is no significant contribution to the schemes from BCC or from other sources.

As part of the phase of work the costs have only been updated for the preferred option and no updates have been applied to the remaining short list options from the previous phase. As such, the preferred option selection decision process has not been revisited. Nonetheless, inspection of the additional costing work that has been undertaken shows that if the costs of the other short list options were to be updated, the cost reductions would be similar, leading to a similar conclusion on the preferred option.

3.5 Fluvial benefits

The main purpose of the new tidal flood defences outlined in the preferred option is to prevent tidal flooding. However, the defences will have an additional benefit of protecting against fluvial flood risk along the New Cut and in the Floating Harbour. As part of this additional phase of work it was agreed with BCC to undertake an additional six model runs to help identify the fluvial benefits / impacts of the Strategy. Another reason to undertake the additional fluvial modelling was to ensure that OM2 properties were not 'double counted' in the Partnership Funding assessment.

An overview of the additional fluvial modelling runs which have been undertaken is provided in the Additional Modelling Report. In summary, the following runs were simulated to identify the fluvial benefits / impacts:

- Two runs (20 year fluvial and 75 year fluvial) for the present day (2015) based on the Do Minimum scenario i.e. baseline fluvial risk. Tidal base flow used.
- Two runs (20 year fluvial and 75 year fluvial) for the present day (2015) based on the Preferred Option scenario (low walls). Tidal base flow used.
- Two runs (200 year fluvial) for 2030 and 2065 to consider fluvial impacts. Preferred option in place (low walls) with a tidal base flow.

A comparison of the present day Do Minimum 1:20 and 1:75 year events and the 1:20 and 1:75 year events with the preferred option in place (low walls) shows that the preferred option does not make fluvial flooding worse during these scenarios. Areas of flooding for the 1:200 year scenarios were similar, with expected variances in flood extents and depths associated with the magnitude of each event.

Table 3-14 below presents the numbers of properties at risk from 1:20, 1:75 and 1:200 year fluvial events with and without the preferred option. It demonstrates that for high return period events (i.e. the present day 1:200 year) the number of properties at risk within central Bristol decreases when the preferred option is in place. For lower return period events, (i.e. present day 1:20 and 1:75 year) there is no difference in the properties at fluvial risk with and without the preferred option. This is because the properties at risk during these events are not located behind the proposed defences but elsewhere within the city centre, most likely at areas upstream of Netham or on the south bank of the New Cut where fluvial risk is known to be an issue. In the future the extent of fluvial flooding is expected to increase and therefore the defences will provide a greater benefit during the lower return period events.

Table 3-14. Properties at risk from fluvial events with and without the preferred option defences

Fluvial flood event	Numbers of properties at risk without defences	Numbers of properties at risk with preferred option defences	Numbers of properties benefitting
Present day 1:20	114	114	0
Present day 1:75	225	225	0
Present day 1:200	2116	1890	226

It was beyond the scope of the Strategy to undertake a full suite of fluvial (or various combined event) model runs and therefore it has not been possible to derive or monetarise the additional fluvial benefits. This approach was agreed with the project board.

The numbers of properties at risk from a range of fluvial events with and without the preferred option in place (Table 3-14) help to illustrate how the fluvial flood risk will change with the preferred option and it is clear that for the present day, during larger magnitude events, the tidal defences will provide additional fluvial benefit. Further studies and modelling runs will be required to monetise this benefit but for this phase of work the economic assessment is considered to be conservative in this respect (i.e. it is under-counting potential benefits).

4 PARTNERSHIP FUNDING CALCULATIONS FOR SCHEMES

4.1 Overview

Partnership funding scores for the schemes which comprise the preferred option have been undertaken.

To derive the Partnership Funding scores the defences have been grouped into schemes according to the phasing plan outlined in chapter 2; a scheme for the Floating Harbour and Totterdown defences and a scheme for the New Cut defences.

The scheme for the Floating Harbour and Totterdown defences includes the defences at Entrance Lock, Cumberland Road underpass, Bathurst Dam, Netham and Totterdown. As discussed in chapter 2, it is necessary to deliver these defences at the same time in order to fully realise the benefits from the Floating Harbour and Totterdown sub-cells.

The New Cut scheme includes the defences at Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road. These defences have been grouped together as they are the defences scheduled for epoch 2 of the Strategy (from 2030).

The baseline for the Partnership funding calculations is the Do Nothing scenario. This is in line with Environment Agency guidelines, as per FCERM appraisal guidance. This is also in accordance with a steer from the Environment Agency during the last phase of work. The partnership funding scores using a Do Minimum baseline are less favourable which highlights the importance of the continued operation of the Floating Harbour to the total flood damages within the study area and the reliance on human intervention and continued management to operate the water level control structures within the harbour.

The revised phasing of the preferred option specifies construction of low defence schemes in epochs 1 and 2. For the purpose of the calculations it has been assumed that schemes will be implemented in the first year of the time epoch for which they are scheduled (i.e. present day for epoch 1 and 2030 for epoch 2). The Floating Harbour and Totterdown / St. Phillips defences are scheduled for construction in epoch 1 and therefore have a base date of the present day for the PF calculations. The New Cut defences (Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road) are not scheduled until epoch 2 and therefore the base date for the PF calculations for these schemes is 2030. With a 2030 base date the period over which benefits are accrued is delayed and the property counts to derive the OM2 benefit is based on properties at risk in 2030 (rather than present day).

Costs for detriment mitigation have been included in the partnership funding calculations because it is assumed that consent for the schemes will be difficult to attain without the necessary mitigation in place. The total costs for mitigating the impact of low defences have been distributed between the Floating Harbour and Totterdown schemes. No detriment costs have been included in the New Cut scheme to avoid double counting of the costs. This is reasonable because it has been assumed that this scheme will only be undertaken if the Floating Harbour and Totterdown schemes are already in place (and therefore detriment mitigation will already be in place).

As part of this stage of work additional fluvial runs in 2015 were undertaken; 1:20, 1:75 and 1:200 year runs which correspond to the OM2 property risk bands in the PF calculator. The properties which remain at risk from this source (during the equivalent tidal events after defences have been constructed) have been counted and excluded from the OM2 benefit assessment.

The Partnership Funding calculations indicate the potential amount of government Grant in Aid (GiA) funding which may be available for the schemes. The New Cut Partnership Funding score which has a 2030 base date is indicative as it represent a ‘jump forward’ in time and is based on projected flood risk which may not develop as anticipated. The Partnership Funding calculation should be revisited closer to the time of the construction.

4.2 Properties Benefitting and Deprivation Classification

To complete the Partnership Funding calculator the properties in the defence benefit areas have been categorised into deprivation classifications under the OM2 outcome measures as specified by Defra (2011). This category relates to the number of households which are moved from one flood probability category to another. The amount of Grant in Aid (GiA) available is dependent on the deprivation area being considered and the number of properties applicable. These categories and their associated payment rates are shown in Table 4-1.

Table 4-1. Deprivation area classifications and the payment rate associated with each

Deprivation Classification	Payment Rate	Example of funding level based on moving one household from very significant risk to low risk for 50 years
20% most deprived area	45p per £1	£15,399 per household protected
21-40% most deprived areas	30p per £1	£10,266 per household protected
60% least deprived areas	20p per £1	£6,844 per household protected

In the last phase of work as part of the initial preferred options assessment all affected properties were classified as falling within the 21-40% most deprived category.

For this update each of the properties has been assigned an Index of Multiple Deprivation (IMD) rank which relates to the project benefit area. This was taken from the National Receptor Database (2011) and the Office for National Statistics (2016). Further detail relating to the NRD data can be found in the 'Economic Appraisal – Briefing Report' (AECOM 2016).

The updated property figures were inputted into the OM2 section of the Partnership Funding calculator in order to estimate the amount of Grant in Aid (GiA) available for the schemes. The properties which would remain at fluvial risk following the introduction of the tidal defences were also considered to avoid double counting of the OM2 benefits.

Table 4-2 shows the number of households which will be better protected against flood risk as a result of introducing low defences in epoch 1. The numbers refer to the properties in the various risk bands benefiting from the defences at the Floating Harbour and Totterdown. The properties in the New Cut flood cells are not included as these defences are not scheduled for construction until epoch 2 under the new phasing approach.

Table 4-2. Number of households better protected against flood risk in epoch 1 with the introduction of low walls at the Floating Harbour and Totterdown (relative to the Do Nothing scenario)

Deprivation Category	Moderate Risk	Significant Risk	Very Significant Risk
20% most deprived areas	173	47	105
21-40% most deprived areas	93	112	270
60% least deprived areas	94	108	201

The low defence schemes assessed in the Partnership funding assessment are to be implemented in epochs 1 and 2 of the Strategy and the standard of protection by the end of the scheme life will fall to between 1:75 and 1:200. In the OM2 calculations this corresponds with the moderate risk band and therefore in the partnership funding calculator it has been assumed (conservatively) that the OM2

properties which are protected by the scheme will fall in the moderate risk band at the end of the scheme life. Additional modelling runs with the individual schemes in place would be required to identify if any of the properties would fall in the OM2 low risk band.

4.3 Partnership funding scores summary

Table 4-3 outlines the raw partnership funding scores for the low defence schemes using the Do Nothing scenario as a baseline. In cases where the Partnership Funding score falls below the 100% threshold, the table also provides an estimate of the cash shortfall that is required to make up the shortfall and achieve a score of 100%.

Partnership funding calculations have been undertaken for the schemes outlined in the phasing plan; including a scheme for the Floating Harbour and Totterdown / St. Phillips defences and for a scheme for the New Cut defences.

Table 4-3 Partnership Funding scores for the preferred option schemes

Scheme	Base date for calculation	Raw Partnership Funding Score	Estimated funding shortfall to achieve 100% score	Estimated level of GiA funding available should score reach 100%
Floating Harbour and Totterdown / St.Phillips defences	Present day	133%	£0	£42.9m
Net Cut defences	2030	13%	£16.1m	£2.4m

Table 4-3 shows that the raw Partnership Funding scores vary for the different low defence schemes . The Floating Harbour and Totterdown / St. Phillips scheme has the strongest score of 133%. This score is well above the typical PF threshold (around 100% but variable) for approval.

The New Cut scheme (2030) has a score 13%. This scheme will require significant contributions in order to achieve a PF score above the funding approval threshold. To achieve a score of 100%, a contribution of approximately £16.1m will be required. Possible sources for a funding contribution for the schemes are from BCC, LEP, other public funding sources and beneficiaries from the defences.

The partnership funding scores are discussed in more detail overleaf.

4.4 Floating Harbour and Totterdown / St. Phillips defences

The Floating Harbour and Totterdown scheme is scheduled for epoch 1 of the Strategy. The scheme consists of four individual defence lengths around the Floating Harbour (Entrance Lock, Cumberland Road underpass, Bathurst Dam and Netham) and a single length of defence at Totterdown between rock's Bridge and Sparke Evans Park near St Phillip's Causeway. The defences provide protection to the Floating Harbour and Totterdown sub-cells and in order to achieve the full benefits it is necessary for all the defences to be constructed. **Table 4-4** presents a summary of the Partnership Funding calculation. The calculation shows that the scheme(s) receive a score of 133%. The amount of GiA likely to be available would be approximately £42.9m.

Table 4-4 Summary of the partnership funding score for combined Floating Harbour and Totterdown scheme (present day)

Funding parameter	Value (£k, unless stated)
Whole life PV costs	49,160
Design and construction costs	42,900
*OM 1 – Economic benefit	1,065,770
OM 2 – Households at risk from flooding	24,490
OM 3 – Households at risk from erosion	0
OM 4 – Statutory Environmental obligations met	0
Total GiA contribution	42,900
Raw outcome measure (OM) score	133%
External contributions (private) required (to achieve a score of 100%)	0
FDGiA sum for approval (towards upfront costs) assuming contributions to achieve 100% if required	NA

**note: OM 1 refers to the total PV benefits of the option less benefits paid for or payments made under the other outcome measures.*

4.5 New Cut defences

The New Cut scheme consists of four individual defences which have been grouped together (Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road). These defences have been grouped as they are each scheduled for epoch 2 of the Strategy, from 2030 onwards (according to the updated phasing of the preferred option).

Table 4-5 presents a summary of the Partnership Funding calculation. The calculation shows that the scheme receives a score of 13%. The scheme would require approximately £16.1m of contributions to achieve a score of 100% and attract GiA funding. If a Partnership Funding score of 100% were to be achieved, then the amount of GiA available would be approximately £2.4m.

For the New Cut defences the Partnership Funding calculation has been undertaken using 2030 as a base date. Closer to the time of construction, the calculation will need to be revisited to re-assess the funding case using the latest guidelines at the time and the most up to date information on flood risk. The New cut scheme is not scheduled until 2030 and by this time there could be new funding arrangements in place for acquiring GiA. In addition, by this time there will be a new modelling baseline and updates to the economic assessment will be required given that the Floating Harbour and Totterdown / St. Phillips schemes will have been constructed. Flows from the New Cut sub-cells into the Floating Harbour during high magnitude events could also be captured to potentially increase the scheme benefits.

Table 4-5 Summary of the Partnership Funding score for New Cut defences (2030 base date)

Funding parameter	Value (£k, unless stated)
Whole life PV costs	19,390
Design and construction costs	18,440
*OM 1 – Economic benefit	32,290
OM 2 – Households at risk from flooding	3,530
OM 3 – Households at risk from erosion	0
OM 4 – Statutory Environmental obligations met	0
Total GiA contribution	/
Raw outcome measure (OM) score	13%
External contributions (private) required (to achieve a score of 100%)	£16,040
FDGiA sum for approval (towards upfront costs) assuming contributions to achieve 100% if required	£2,390

**note: OM 1 refers to the total PV benefits of the option less benefits paid for or payments made under the other outcome measures.*

4.6 Combined approach

Prior to updating the preferred option with the latest phasing plan, all the low defences were scheduled to be constructed during epoch 1. This approach is precautionary and does not represent a maximal return on investment. For comparison purposes a partnership funding score based on this approach has also been calculated.

Table 4-6 shows the partnership funding score should all the low defences be delivered together in epoch 1.

With this approach the partnership funding score is 98%. In order to achieve a PF score of 100% a funding contribution of £1.4m would be required.

Table 4-6 Summary of the partnership funding score for combined Floating Harbour, Totterdown and New Cut schemes (present day)

Funding parameter	Value (£k, unless stated)
Whole life PV costs	69,320
Design and construction costs	61,330
*OM 1 – Economic benefit	1,096,900
OM 2 – Households at risk from flooding	28,250
OM 3 – Households at risk from erosion	0
OM 4 – Statutory Environmental obligations met	0
Total GiA contribution	/
Raw outcome measure (OM) score	98%
External contributions (private) required (to achieve a score of 100%)	1,350
FDGiA sum for approval (towards upfront costs) assuming contributions to achieve 100% if required	59,981

**note: OM 1 refers to the total PV benefits of the option less benefits paid for or payments made under the other outcome measures.*

4.7 Discussion

Partnership funding scores have been calculated based upon the phasing plan developed during this work stage; scores for the Floating Harbour and Totterdown in 2015 and the New Cut in 2030. With this approach the Floating Harbour and Totterdown / St.Phillips scheme has the strongest PF score by a significant margin as this scheme protects the majority of assets and properties at risk. The New Cut defences, whilst having a similar cost profile to the Floating Harbour scheme, protect significantly fewer properties and have a PF score of only 13%.

The phased approach to scheme delivery has been endorsed by the project board in February 2017. There is a strong case for funding the schemes in epoch 1 and the approach is favourable in terms of deliverability and maximising returns on investment.

The PF score for the epoch 1 schemes is in excess of 100% which suggests that the defences could be fully funded by GiA. However, the latest DEFRA target is for schemes to deliver a minimum 10-15% external contribution, even if the score is in excess of 100%.

For comparison purposes the partnership funding score for delivering all the low defences in epoch 1 has also been determined (i.e. the combined approach). This was the preferred option prior to updating the phasing plan during this stage of work. The combined approach produces a score of 98% and a funding contribution of approximately £1.4m would be required to achieve a 100% PF score