RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY

Residual Risk

Technical Note

July 2017

Prepared for Bristol City Council

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1 INTRODUCTION

1.1 Overview and purpose of this note

This technical note details how the Strategy has considered the residual risk associated with the Preferred Strategic option with respect to the National Planning Policy Framework (NPPF) (2012).

The need for the technical note was identified by Bristol City Council (BCC) on the suggestion that 'the planning authority may wish to incorporate an appropriately worded planning policy to formalise any identified mitigation requirements'.

The National Planning Policy Framework (NPPF) sets out the Government's planning policies for England and how these are expected to be applied. The Framework includes a section on meeting the challenge of climate change, flooding and coastal change. With respect to flood risk, appropriate exception tests must be passed for development to be allocated or permitted. The NPPF policies and exception tests have been used to scope the content for this residual risk note.

1.2 Strategy preferred option

The residual risk associated with the preferred strategic option has been considered in this technical note. The preferred strategic option involves:

In the short term, from present day to 2030:

- Constructing raised defences at Entrance Lock, Cumberland Road underpass, Bathurst Basin Dam, Netham and Totterdown / St. Phillips.

  The raised defences would be constructed to the 2030 1:200 year standard of protection (in FCERM terms (not including freeboard). The defences constructed to this standard are described as 'low' defences.

- Undertake localised works to the existing defences at Bower Ashton, upstream of Netham and opposite Totterdown on the south bank and provide PLP at Bedminster. These elements of work are needed to mitigate the increased risk of flooding in these areas caused by increased in-channel water levels associated with the raised defences.

In the medium term, from 2030:

- Construct more 'low' defences at Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road.

  The raised defences would be constructed to the 2030 1:200 year standard of protection (in FCERM terms, not including freeboard).

- Maintain the 'low' defences constructed prior to 2030 at Entrance Lock, Cumberland Road underpass, Bathurst Basin Dam, Netham and Totterdown / St. Phillips and also the other mitigation works.

In the longer term, from 2065:

- Raise all the 'low' defences to a 2115 1:200 year standard of protection (in FCERM terms, not including freeboard). The defences constructed to this standard are described as 'high' defences.

  This will be undertaken throughout; at Entrance Lock, Cumberland Road and underpass, Bathurst Dam, Commercial Road, Clarence Road, Cattle Market Road, Totterdown / St. Phillips and Netham.

Figure 1-1 shows the location of the preferred strategic option schemes.

All Standards of Protection referred to in this note are based on the recommended FCERM change factor for climate change (UKCP09 medium emission scenario, 95%tile).

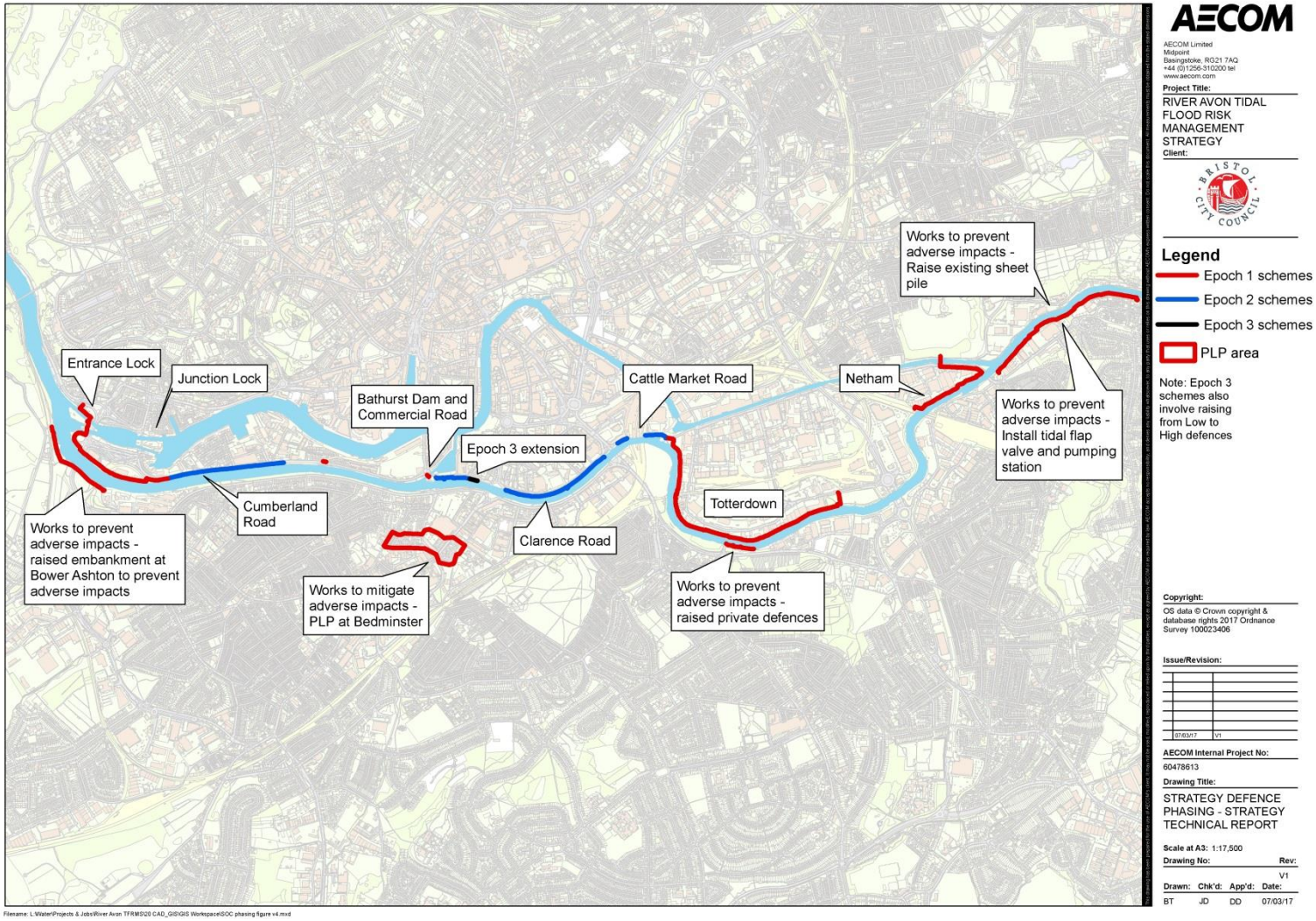

Figure 1-1 . Preferred strategic option schemes and phasing

2 HOW DOES THE STRATEGY REDUCE TIDAL FLOOD RISK AND MINIMISE RESIDUAL RISK

2.1 Managing Uncertainty

2.1.1 *Adaptive approach to Climate change*

There is a large envelope of potential future sea level rise based on the Lower to Upper end climate change scenarios (40-105cm by year 100).

There is a discrepancy between the climate changes allowances used by flood risk management (FRM) authorities, who consider sea level rise based on the 95%tile medium emissions climate change scenario, and local planning authorities who consider the more precautionary Defra 2006 upper end estimate. The discrepancy is an ongoing unresolved national issue, however, prior to 2065 (the start of epoch 3) there is very little difference in sea levels between the two climate change scenarios (approx. 7cm). By 2115 there is a larger difference (approx. 35cm) (see Figure 2-1).

Throughout the Strategy, the standard of protection quoted for the proposed defences is based on the FRM recommended change factor (medium emissions scenario).

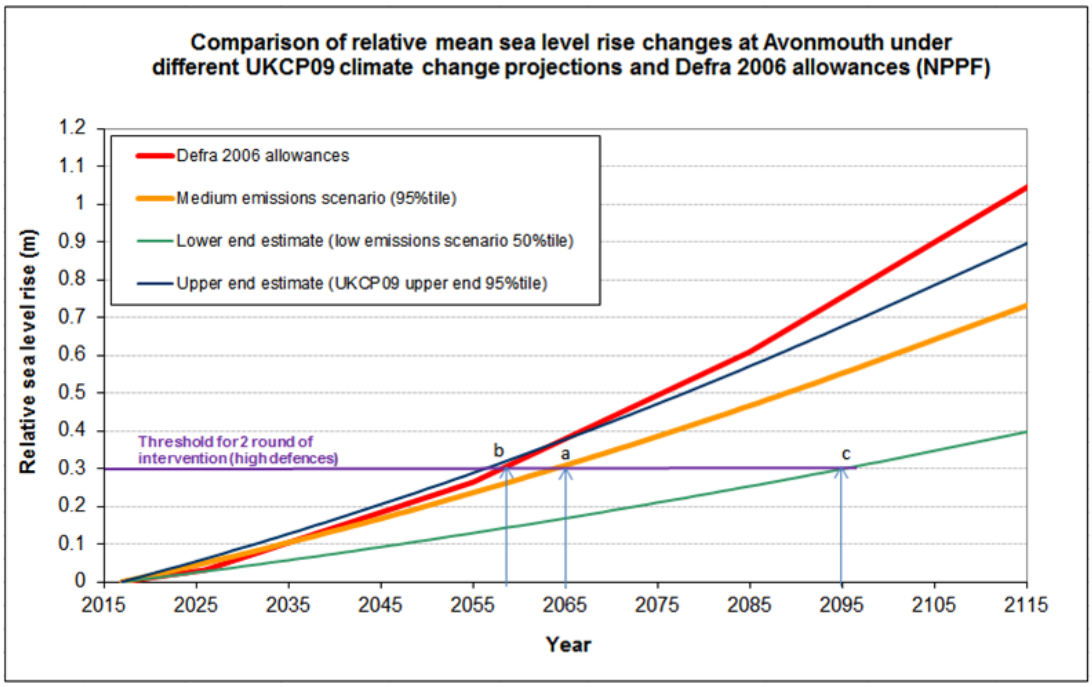

Figure 2-1Comparison of relative mean sea level rise at Avonmouth under different climate change scenarios

2.1.2 *Standard of protection*

In FRM terms the low defences constructed in epochs 1&2 are designed to a 2030 1:200 year SoP (~1:400 yr SoP initially). Thus, due to sea level rise, from 2030 the SoP is expected to gradually fall and will sit above the 1:75 year standard by 2065.

In planning terms, the SoP of the low defences includes the 200mm freeboard allowance (see Figure 2-2) and therefore the minimum 1:200 year SoP is maintained for the first two time epochs even under the upper end (planning) sea level rise allowances (see Table 2-1). Therefore, in planning terms the Strategy preferred option commits to sustaining a crest level in excess or equal to a 1:200 year SoP throughout.

Table 2-1 Summary of defence standards when assessed in FRM and planning contexts.

	Criteria	Entrance lock to Clarence Road	Cattle Market Road to Netham
	As built defence crest level	9.65 ODN	9.80m ODN
FRM	2065 FRM 1:200 year water level	9.59m ODN	9.64m ODN
FRM	Low defence design level (excluding benefit of constructed 0.2m freeboard)	9.45m ODN	9.60m ODN
FRM	Low defence standard in 2065	>1:75	>1:75
Planning	2065 planning 1:200 year water level	9.66m ODN	9.71m ODN
Planning	Low defence crest level (including 0.2m freeboard)	9.65m ODN	9.80m ODN
Planning	Low defence standard in 2065	1:200	>1:200

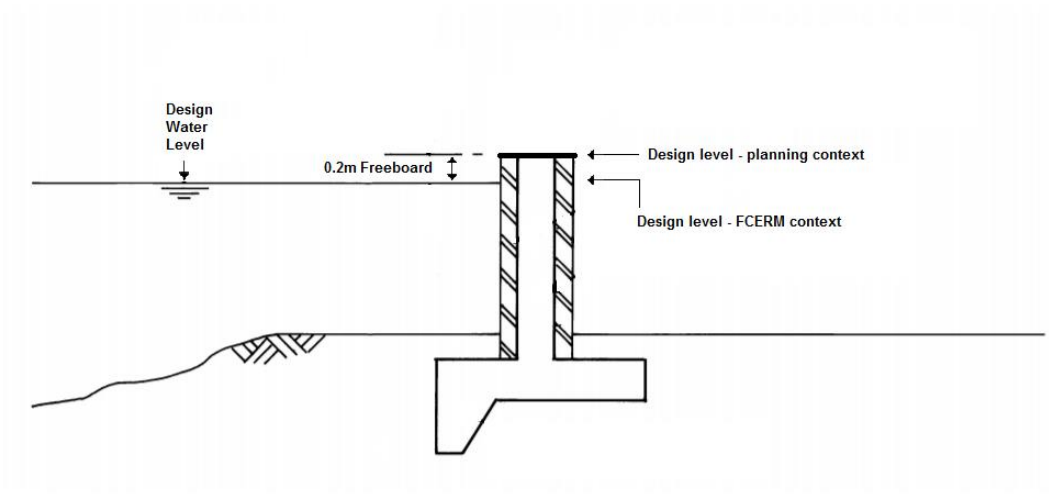

Figure 2-2 Illustrative summary sketch (not actual defence details) drawing showing the difference between planning and FCERM defence design levels and freeboard allowance

Towards the end of epoch 2, should it be apparent that sea level rise is following the upper end climate change scenario, it is essential that BCC have the flexibility to adjust the plans for high defences to ensure that the required planning SoP to year 100 is met. This may involve constructing longer and higher 'high' defences but this assessment can only be made in approximately 40 years from now when the magnitude and rate of sea level rise at the time can be better determined.

If future climate change more closely follows the lower end estimates then the initial low defence implementation will continue to provide the required SoP many years beyond 2065 (to about 2095 – see position 'c' in Figure 2-1), thus delaying the need for future spend and scheme implementation.

The Strategy will increase the standard of flood protection in the areas behind the defences but it is still recommended that developers undertake site specific flood risk assessments and identify any additional measures to reduce the consequences of flooding to developments. For example, developers may need to consider site specific threshold levels / raise floor levels of buildings / provide safe access and egress. The extent to which floor levels may need to be raised may be reduced by the strategy.

2.1.3 *Freeboard*

FRM authorities require a freeboard to be included on all proposed defences to account for some degree of uncertainty and therefore a 200mm freeboard has been included. However, the benefit of the freeboard is not considered in the appraisal, and in FRM terms the standard of flood protection provided by the defences is described by excluding the freeboard allowance.

On the contrary, local planning authorities assess the standard of protection of a flood defence based on actual defence heights at a strategic level (i.e. defences for the flood cell). Individual site thresholds (typically 300mm) are then applied at a site specific level to account for uncertainties. Therefore, in planning terms, the standard of flood protection provided by the strategy defences can be described according to the actual defence crest level (which includes the defence freeboard allowance).

2.2 The design and construction of strategic flood defence infrastructure

2.2.1 *Defence design*

As part of the preferred option for the strategy proportionate geotechnical and structural analysis was applied to key elements / sections of defence designs to identify the likely sizes of the defences. Other defences have been developed based on engineering judgement and rules of thumb. Reinforced concrete cantilever walls have been proposed where defence heights above ground level are less than 2m. Sheet piled walls have been proposed for defences over 2m or where topography meant that cantilever walls were not suitable.

The designs that have been developed consider the defence alignments, level and form and can be used to inform planning by showing which areas of the study area will be protected and to what standard of protection.

The proposed defences have been designed to provide either a new retaining structure or, along the New Cut, to be structurally independent of the existing retaining structures. This minimises the probability that a defence failure could occur following the collapse or partial collapse of the ageing New Cut retaining structures.

The preferred option also involves the construction of new tidal stop gates at the entrance points to the Floating Harbour at Entrance Lock and Netham. The gates will be specifically designed to resist water head from both sides and will need to have a dual flood / lock gate function. The preferred option refinement report specifies that the gates should be constructed with multiple layers of redundancy in power supply and controls to ensure that the gates are resilient to flooding and that the risk of failure is minimised (and is lower than the existing gates). For instance, the gates will need to be powered from both sides of the channel (so that electricity supply failure on one side does not compromise closure), have a backup independent power source and will also need to be fitted to ensure manual operation (in case of complete electrical failure).

The Strategy recommends that in further work best practice is followed to ensure that additional development and refinement of the designs is carried out to create fully dimensional outline designs. These will then need to be developed further to create detailed designs that are suitable for construction. All the designs will include the necessary safeguards / factors of safety.

Defacto defences in their current form will not be relied upon. The one location where existing defences will be incorporated is at Totterdown / St.Phillips for low defences. However, in this location it is specified in the design that additional resilience measures are provided to ensure that they can be relied upon as a robust defence. For high defences, a completely new structure is proposed.

2.2.2 *Minimising breach risk*

There is a remote probability that the raised defences could breach due to structural integrity being adversely affected during construction, installation or by the intervention of a third party (i.e. vehicular /debris impact). However, the probability that this could occur will be minimised by:

- During construction: the defences will be constructed to the relevant codes and standards with appropriate factors of safety. A competent contractor and supervisor will construct the defence to the detailed design specifications and will diligently follow the required checking protocols.
- During installation: BCC will develop a resourced emergency plan to mitigate any issues that may arise during installation.

- Scheduled maintenance and repair to maintain the defence assets will reduce the likelihood of structural failures.

- Impact of a third party: to mitigate the impact of vehicular impact or debris colliding with the defences the relevant construction codes will be followed and sufficient factors of safety will be included in the design. For the defences located adjacent to the highway, the detailed design and construction will need to address the risk of vehicular containment.

- Additional defence height (200mm freeboard) currently included in the design to account for uncertainties (e.g. modelling errors, possibility of small waves) etc. This allowance should be reviewed as appropriate in subsequent studies.

The design and construction processes will minimise the probability of defence failure. However, a potential avenue for further work during further design work would be to undertake additional modelling to establish the residual risk associated with breaching of the different raised defence sections throughout the city, and particularly where flood gates are present as there is a real likelihood (albeit small) of these assets being left open or failing.

2.2.3 *Access and egress*

The flood defence designs for the preferred option ensure that safe access and egress will be maintained. It has been built into the designs where possible and defence alignments have been chosen to provide a minimal impact. For example, at Cattle Market Road, two defence alignments were initially considered. The project team identified access restrictions imposed by the setback alignment and therefore the frontline alignment was recommended and selected as the preferred approach at this stage.

Where existing access and egress routes pass through the proposed defence alignment then passive defences such as ramps have been proposed to minimise the impact. Where possible, passive defences have been used rather than operational defences (such as demountable flood gates) in order to minimise the operational requirements of the Strategy and the residual risk of gates being left open. It is recognised that the inclusion of passive defences may create some landscaping issues within the public realm and landscaping considerations will need to be fully incorporated into the next design phases to ensure the impacts are minimised.

2.2.4 *Operation and maintenance*

The design of the preferred option includes cost allowances for the maintenance of the new defences and for the operation of the Floating Harbour water level control infrastructure. The costing has remained at a strategic level and in future design work more detailed specifications for the maintenance activities will be required.

The operational costs for the Floating Harbour have been adjusted to account for sea level rise during the appraisal period. The frequency of operation, such as pre-lowering of the harbour, pre-event planning, and inspections and repairs is expected to increase in the future and an allowance has been made for this.

It is envisaged that BCC will be responsible for the operation and maintenance of the new raised defence assets and will continue to operate the Floating Harbour water level control infrastructure, such as the new flood / stop gates at Entrance Lock and Netham. By BCC taking this responsibility (rather than different parties) it will allow for a coordinated planned approach which will help to minimise the risk of raised defence flood gates and the lock flood / stop gates being left open.

2.2.5 *Design of development to manage and reduce flood risk wherever possible*

Compared to the Do Minimum scenario the preferred strategic option reduces flood risk throughout the city through the implementation of raised defences and controls to stop water entering the Floating Harbour during extreme tidal events. In total 3392 properties in the study area will benefit from the Strategy through a reduction in flood risk.

The preferred option will incorporate development opportunities into the defences where possible. For example, at the Totterdown / St. Phillips defence alignment for the construction of high defences (from 2065) it is expected that by this time period many of the existing buildings / properties along this reach have / will be redeveloping. The preferred option recommends that BCC work alongside the developers

to ensure that the defences are incorporated into redevelopment proposals. It is likely that this will need to be undertaken on a piecemeal basis, as and when areas are proposed for redevelopment.

2.2.6 ***Resident awareness and flood warning and evacuation procedures***

Bristol City Council and the Environment Agency already have emergency planning procedures in place, and advise residents on flood awareness and provide flood warnings prior to events. Under the preferred strategic option it will be necessary for these activities to continue to ensure that the residents remain aware of the flood risk, how to prepare before flooding and the emergency procedures in case flooding occurs.

2.2.7 ***Considering the characteristics of a possible flood event, e.g. the type and source of flooding and frequency, depth, velocity and speed of onset***

The development of the preferred option has been supported by detailed numerical modelling which simulated tidal flood events for a number of return periods. The modelling considered joint probability tidal and fluvial and provided the project team with a detailed understanding of the type and source of flood risk. The model provided outputs including depth, direction and velocity of flooding which was used as the basis to come up with management interventions for the preferred strategic option.

2.2.8 ***Funding arrangements necessary for implementing the measures***

The approach to acquiring the necessary funding for the preferred option has been investigated and is presented in the Funding Strategy.

Partnership funding calculations have been undertaken to establish the likely amount of Grant in Aid (GiA) funding that would be available for the first two phases of defences (the defences scheduled for the short and medium term, see section 1.2).

The partnership funding score for the initial works at Entrance Lock, Cumberland Road underpass, Bathurst Dam, Netham and Totterdown and the mitigation works is greater than 100%. This suggests that a significant proportion of GiA for these works will be available.

The partnership funding score for the second phase of works at Cumberland Road, Commercial Road, Clarence Road and Cattle Market Road is below 100%. It is likely that these works will require funding from other sources / mechanisms.

Alternative funding sources which could be used for each phase of the Strategy implementation include:

- Local Enterprise Partnership Funding Economic Development Fund (EDF)
- Local Enterprise Partnership Funding Revolving Infrastructure Fund (RIF)
- City centre BID
- Private investment
- Community groups
- Coastal Communities Fund
- Local Levy funds
- Community Infrastructure Levy
- Devolution Deal
- Lead Local Flood Authority funding (BCC)
- Development opportunities - synergies and efficiency savings

A summary of the likely amounts of funding available for these different sources is provided in the funding strategy. Significantly, £5m has been fully allocated from both the LEP EDF Tranche 1 (in 2023-24) and Tranche 2 (2032-33).

3 SOURCES OF RESIDUAL RISK

Although delivery of the Strategy will reduce strategic flood risk considerably, there will still be a potential residual risk associated with the aspects discussed in this chapter.

3.1 The failure of flood management infrastructure, such as breach of a raised defence

The residual risk of failure of the raised defences has been considered in the development of the preferred option. Further work and additional modelling was undertaken during the preferred option refinement stage to investigate the residual risk associated with a breach of Entrance Lock and Netham.

The additional model runs for breach risk included:

- One run (200 year tidal) for 2115 with the preferred option in place (high defences) but with Netham in an open position
- One run (200 year tidal) for 2115 with the preferred option in place (high defences) but with Entrance Lock in an open position. Junction Lock remained closed during this simulation.

Junction Lock refers to the two pairs of existing stop lock gates at the eastern end of Cumberland Basin. The gates are operated by HPUs and HPU and emergency manual override provided by the EA and are owned/maintained/operated by BCC.

A further model run with the preferred option in place (high defences) but with both Junction Lock and Entrance Lock gates open was also included although this is not considered a breach scenario as it is considered extremely unlikely to occur as for this event to occur it would require the failure of two separate power supplies (to each set of gates) and the operational protocol for manual override at both locations to not be carried out.

A detailed description of the flood risk associated with the breach modelling runs is provided in the Additional Modelling Report. Flood risk maps for each scenario are provided in Figure 3-1 to Figure 3-2.

3.1.1 ***Breach at Entrance Lock***

In the scenario when Entrance Lock is left open, water can freely flow into Cumberland Basin from the River Avon. During this simulation, Junction Lock is closed with the crest heights of the lock gates set at 8.73m AOD and 8.53m AOD (i.e. the present day situation). The gates at Netham are also closed during this scenario.

During the first two tidal cycles, the water level in the Cumberland Basin does not reach the height of the Junction Lock gates and water is therefore retained within the Cumberland Basin with no overtopping occurring. During the third and fourth (peak) tidal cycles, the Junction Lock gates are overtopped and water flows into the Floating Harbour. This leads to flooding in areas around the Entrance Lock and Junction Lock, Victoria Street in Temple Back and at St Philips. There is no overtopping at the Netham Lock gate in this scenario.

The likelihood of this event occurring is very low. The likelihood and potential mitigation should a breach occur are discussed later in this section.

3.1.2 ***Breach at Netham***

For the scenario when Netham gates are left open, both Junction Lock gates and Entrance Lock gates remain closed. The model run also conservatively assumes that there will be a failure to deploy the existing manually operated gates at Netham (which effectively act as stop gates, although they can be overtopped and outflanked).

The results from the scenario when Netham gates are left open show that flooding occurs within the Floating Harbour area.

Depths of between 1.00m and 2.00m are experienced in Netham and St Phillips however flood depths in some areas are reduced when compared with the Do Minimum in these areas. This is because defences along the River Avon at Netham prevent overtopping and with the Entrance Lock gate closed and raised, there is more storage within the Floating Harbour.

The likelihood of this event occurring is very low. The likelihood and potential mitigation should a breach occur are discussed later in this section.

3.1.3 *Summary of breach results*

The breach scenarios demonstrate how the existing assets at Junction Lock and Netham Lock will continue to be important in the future should the new gates at Entrance Lock or Netham fail open or breach.

There is a significantly reduced flood extent in the scenario when just Entrance Lock is left open compared to the Do Nothing scenario when Junction Lock is left open and there are no control structures at Entrance Lock included.

Furthermore, whilst only one breach event was modelled at Netham, deployment of the existing lock gates in this location may help to reduce the flood extent should the new gates at Netham fail open or breach.

3.1.4 *Likelihood of gate breach and potential mitigation*

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

It should be noted that for each breach scenario the model has been simulated with a defence failure of 70 hours at each location. This represents a conservative approach as realistically there would be an emergency contingency plan in place should one of the lock gates fail or be left open.

BCC have existing operational emergency plans, proven through the deployment of a temporary flood barrier in advance of the tidal surges during 2013-15. In the unlikely event that a breach should occur, as a contingency it is recommended that BCC update the emergency plans and include plans for 'making safe' a breach (i.e. through suitable planning / exercising / resourcing).

3.1.5 *Risk associated with manually operated defences (e.g. flood gates)*

The additional model runs which have been undertaken have focussed on the flood / stop gates at Entrance Lock and Netham. However, at various locations the design also includes manually deployed flood gates within the defence alignment, necessary to maintain access requirements across the defences during non-flood conditions.

The manually deployed flood gates are situated at;

- Entrance Lock (x2);
- Cumberland Road and underpass; and
- Totterdown / St. Phillips (x2 – both for high defences)

The use of passive defences (such as ramps) to maintain access has been preferred wherever possible. Where passive defences could not be used the use of temporarily deployed flood gates increases the residual risk of defence failure as there is a chance that the gates could be left open during flood events. In the event of a temporarily deployed flood gate being left open, the flow pathway through the defence would be limited and the amount of flooding that would be expected to occur is significantly less than a breach to either the of the main gates at Entrance Lock or Netham,

It is recommended that operational procedures are put in place to ensure that BCC have a team to operate and close the temporarily deployed flood gates during events. Effective operation will rely on the continued forecasting and warning of flooding prior to events. Instructions to close the gates should be provided with sufficient time to reduce the risk of the gates being left open.

3.1.6 ***Further work***

Additional work to investigate the residual risk associated with the manually operated flood gates being left open is recommended. It has been agreed by the project team to undertake additional model runs to

test open of the manually operated gates at Cumberland Road, Cumberland Road underpass and St. Phillips (reaches 1-20, 3-1 and 7-13, see preferred option development report for reach locations).

In addition, the risk associated with a breach of different raised defence sections could be investigated further, for example, a breach to the flood walls at Cumberland Road or Totterdown. Although improbable, a breach to the raised defences during the instance of an extreme tidal event, could occur due the structural integrity being adversely affected during construction, installation or by the intervention of a third party i.e. a vehicular / debris impact. The actions which will be undertaken to limit the risk of breaching are discussed in section 4.

Work to determine the likelihood of a breach occurring to the raised defences would also be useful to contextualise the potential impacts and the overall residual risk.

It has been agreed by the project team to undertake additional modelling to test a 10m wide breach of the raised defences at reaches 4-1 (Bathurst Basin Dam), 5-3 (Clarence Road), 7-6 (St. Phillips), 7-27 (St. Phillips) and 8-2 (Netham). A 20m wide breach will also be tested at reach 2-1 (Cumberland Road) as a sensitivity test. Refer to the preferred option development report for reach locations.

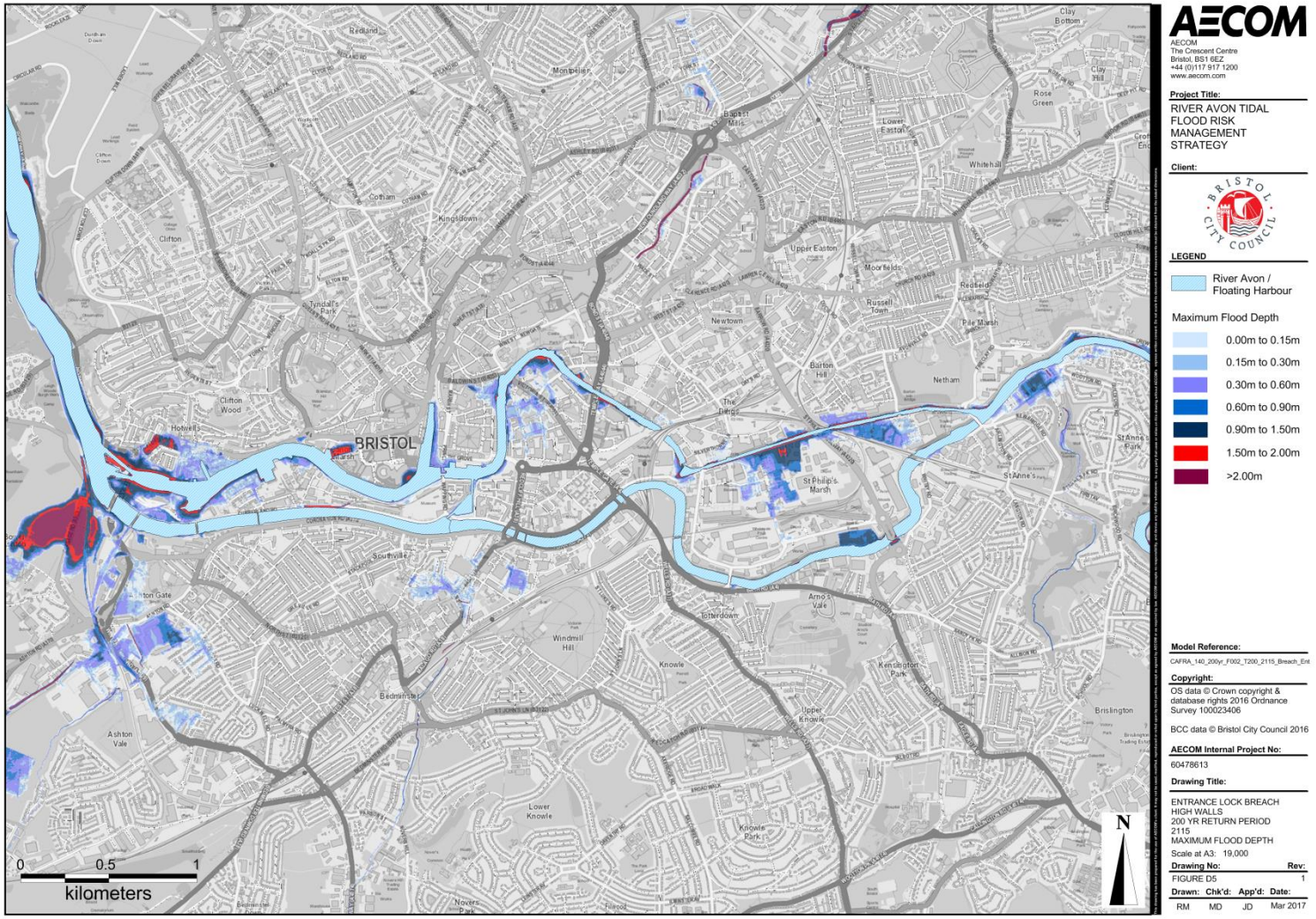

Figure 3-1. Flood extent and depth; Entrance Lock breach scenario with high defences (Junction Lock closed); 1:200yr 2115

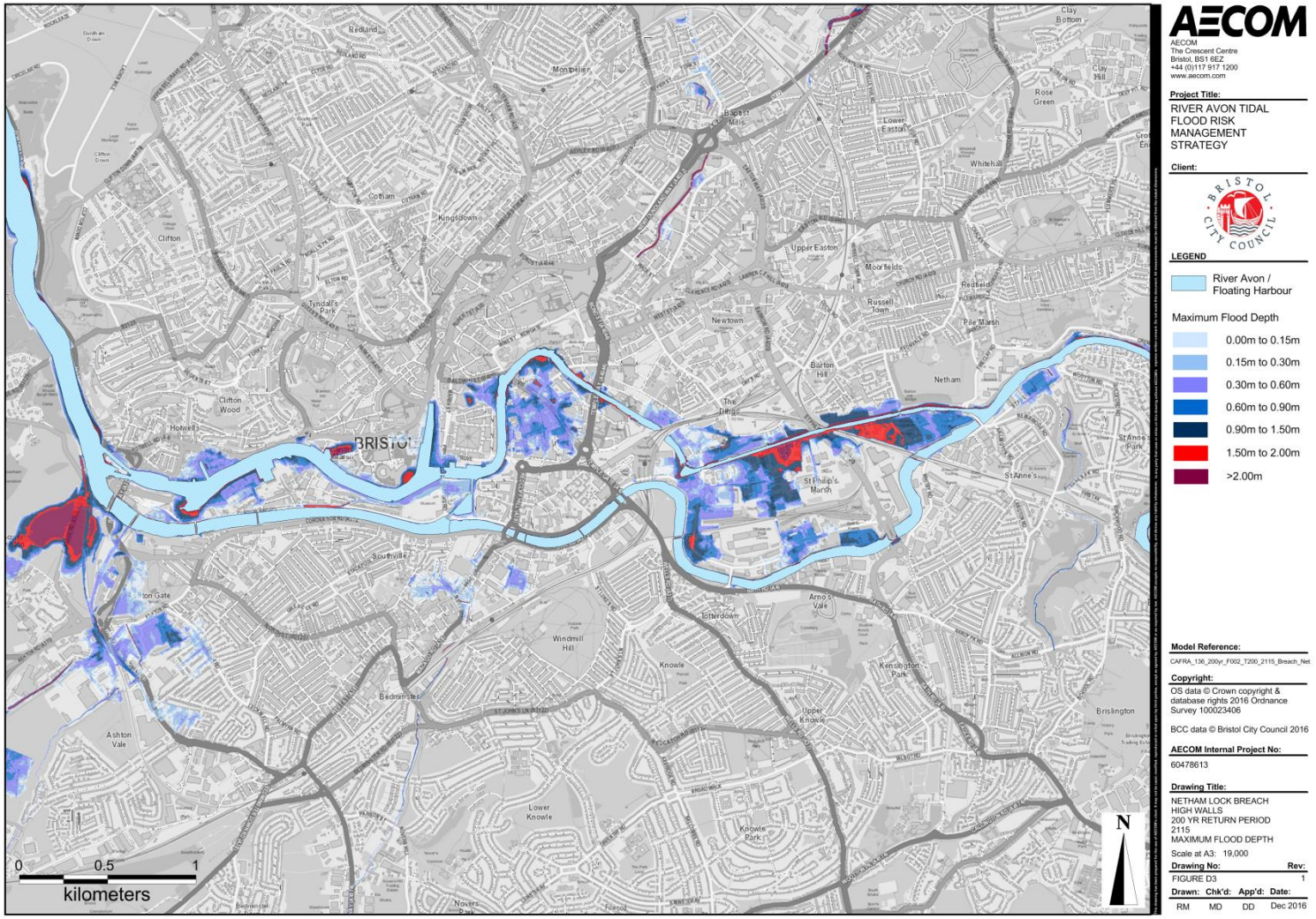

Figure 3-2. Flood extent and depth; Netham breach scenario with high defences, 1:200yr 2115

3.2 A severe flood event that exceeds a flood management design standard, such as flood that overtops a raised flood defence

Further work and additional modelling has been undertaken during the preferred option refinement stage to investigate the impacts of above design standard flood events and the risk associated with the proposed defences being inundated / overtopped. These simulations included a 1000 year tidal event combined with a 12 year fluvial event for 2015, 2030 and 2065 with the Preferred Option in place. Flood risk maps for each scenario are provided in Figure 3-3 to Figure 3-5.

In summary:

1 in 1000 year tidal event combined with a 1 in 12 year fluvial event (2015) and preferred option in place – Overtopping of the flood defences around Entrance Lock and Cumberland Road results in inundation of Spike Island with flood depths reaching approximately 0.7m along Mardyke Ferry Road. Defences along both Commercial Road and Clarence Road are overtopped which leads to flooding around Bathurst Basin and Redcliffe (flood depths reaching approximately 1.05m along Chatterton Street and 0.47m along Temple Gate). The Totterdown and Netham defences are also overtopped which leads to flooding through St. Phillips Marsh and the industrial area by Netham Lock.

1 in 1000 year tidal event combined with a 1 in 12 year fluvial event (2030) and preferred option in place – When compared to the 1:1000 year event for 2015 overtopping occurs in all the same areas along the River Avon with flood extents and depths slightly greater. For example, depths along Mardyke Ferry Road, Chatterton Street and Temple Gate increase to approximately 0.78m, 1.10m and 0.65m respectively. There are also new areas to the north of the Floating Harbour (around Victoria Street in the Temple Back area and Welsh Back) which flood given the higher fluvial flows.

1 in1000 year tidal event combined with a 1 in 12 year fluvial event (2065) and the preferred option in place – Overtopping of the same defences (as above) occurs during the peak of the tidal cycle and flood depths increase at Mardyke Ferry Road and Chatterton Street (rising to 1.00 and 1.10m respectively).

More detail on the flood risk from these events is provided in the additional modelling report. To summarise, the level of risk varies across the city but it should be recognised that the strategy is unable to completely protect the city from flooding. Irrespective of the standard of protection provided, there will always be the potential for events which exceed the crest level of the defences and cause flooding. For instance, even if a defence is constructed to a 1:1000 year standard of protection, there is still the residual risk that a 1:2000 year event could occur (albeit, very small). By undertaking the additional work, the strategy has demonstrated which properties will be at risk from above design standard events and provided a better understanding of the residual risk associated with the above design standard events.

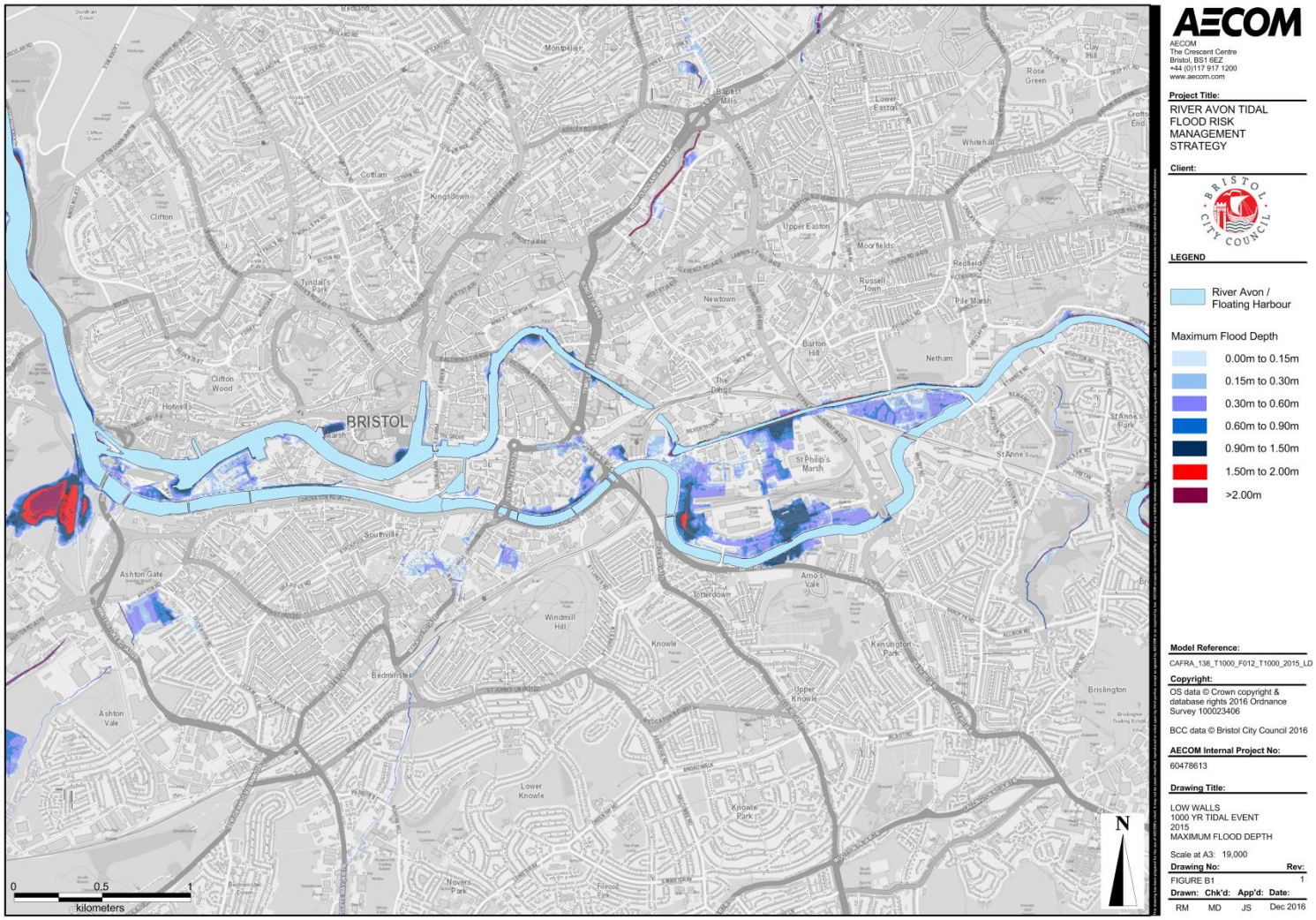

Figure 3-3. Flood extent and depth; 1:1000 year tidal event with low defences 2015

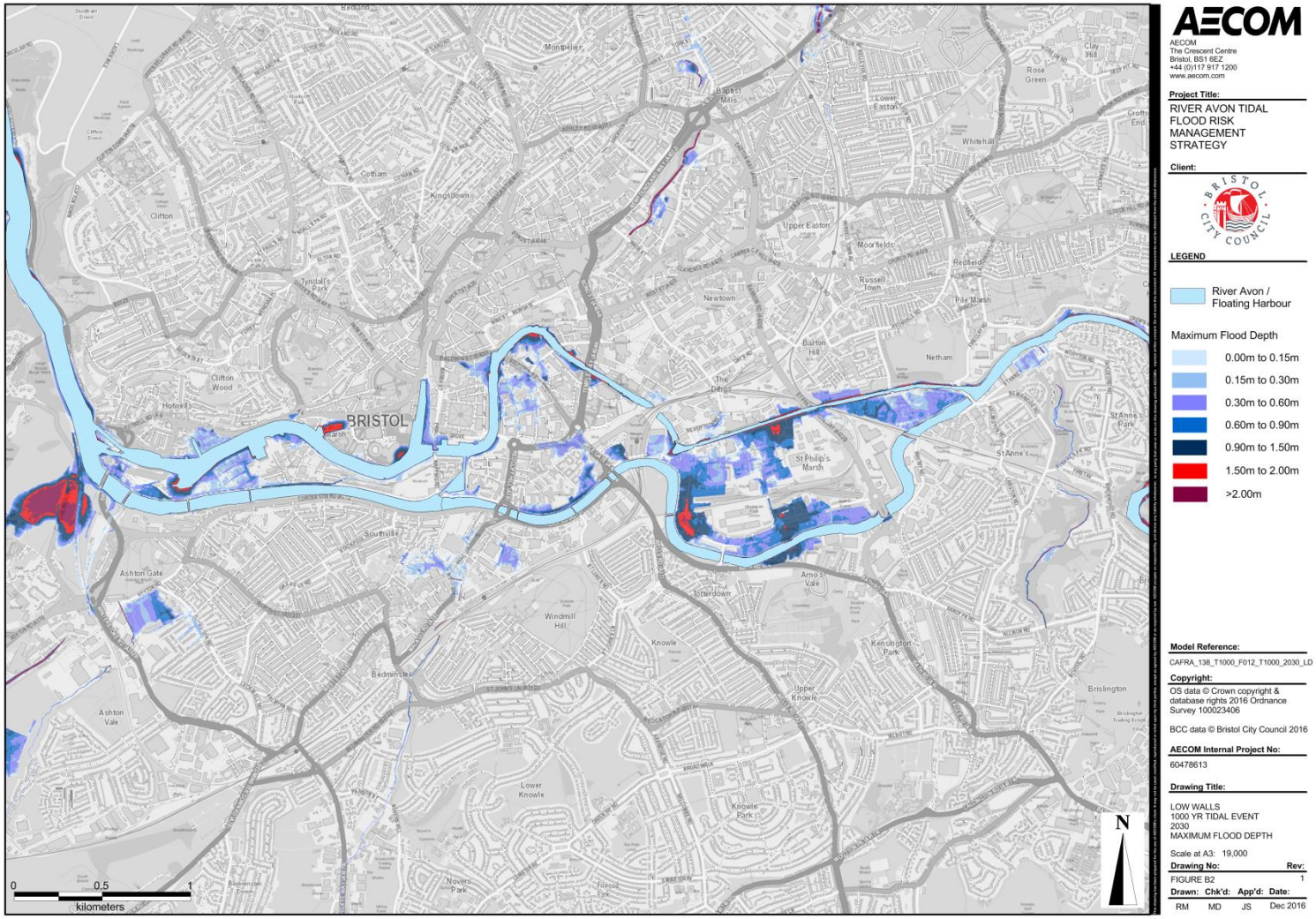

Figure 3-4. Flood extent and depth; 1:1000 year tidal event with low defences 2030

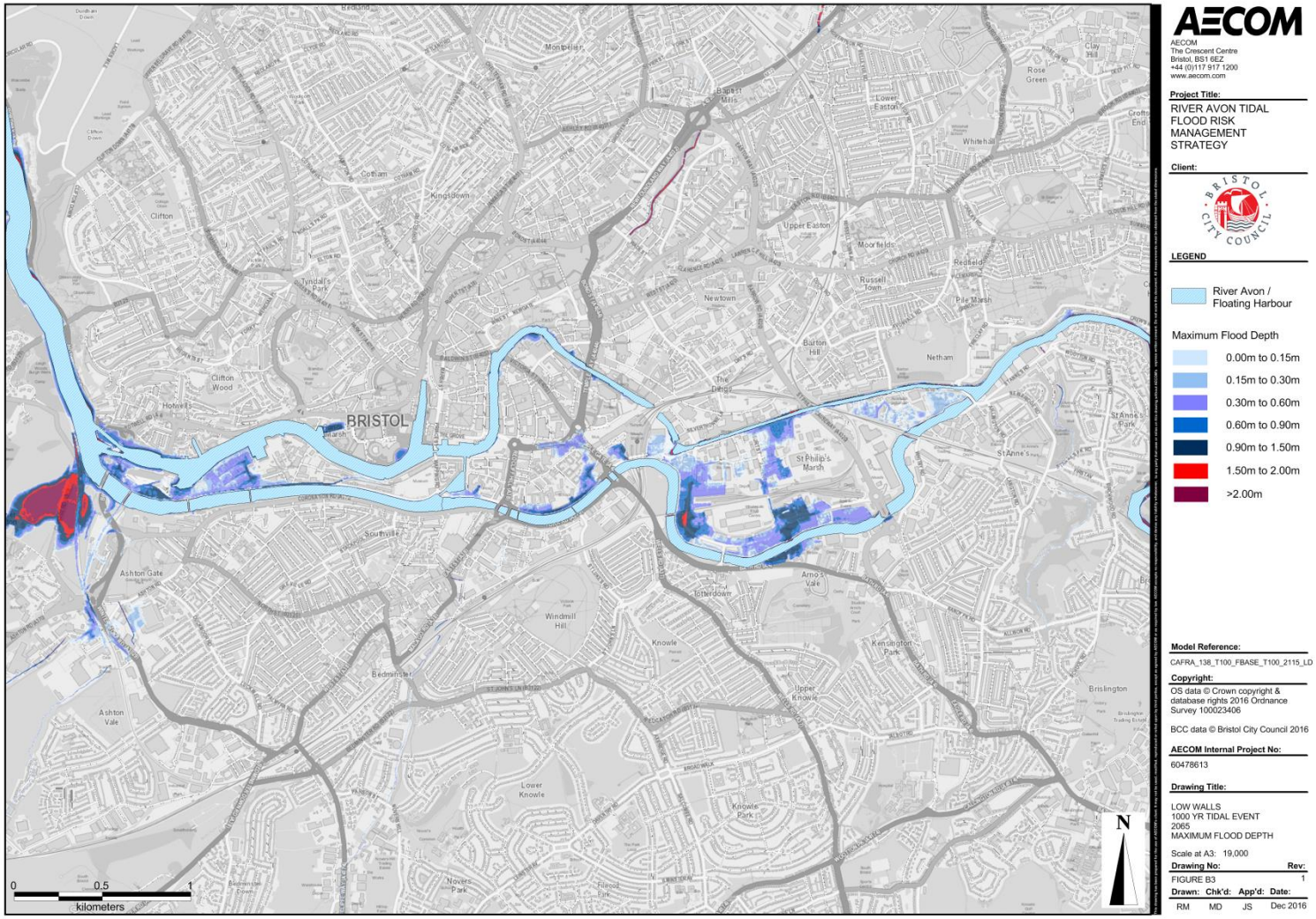

Figure 3-5. Flood extent and depth; 1:1000 year tidal event with low defences 2065.

4 HOW CAN DEVELOPMENT BE MADE SAFE CONSIDERING RESIDUAL FLOOD RISK?

The Strategy reduces strategic flood risk which should reduce site level mitigation requirements for development. In addition, a number of measures are incorporated into the preferred option to minimise the residual risk of flooding (i.e. including multiple levels of redundancy into the new gates at Entrance Lock and Netham). However, residual flood risk will still need to be considered at a site specific level through FRA and application and demonstration of the NPPF sequential test. SFRA2 guidance should be followed when developing and determining site specific flood risk mitigation requirements.

This chapter outlines site specific measures which can be undertaken to make development safe from residual flood risk.

4.1 Design of buildings to avoid flooding by, for example, raising floor levels

Raising floor levels can reduce a buildings vulnerability to flooding and help to make safe a development from residual flood risk. By implementing the Strategy the required standard of protection for the next 100 years will be implemented which may reduce the requirement to raise floor levels of new development in Bristol. Consideration of residual risk on a site by site basis will be required and specific and suitable mitigation provided. The residual risks considered and accounted for over the proposed life of the development should include the above design event flood risk, potential breach risk and other sources of flooding (e.g. surface water flood risk).

4.2 Ensuring space is left in developments for flood risk infrastructure to be maintained and enhanced

Environment Agency byelaws extent 8m from the top of the river bank or existing retaining/defence structure, and so currently provide a control over development of third party land for much of the proposed alignment.

Every effort has been made to ensure that the preferred option defence alignments are on BCC owned land and do not impede onto the existing urban landscape or future developments. In some instances this is not possible; for example, the construction of high defences at Totterdown / St. Phillips requires a significant amount of space which is not currently available. Where the preferred alignments impede into potential development areas/privately owned land the strategy recommends that BCC work alongside the developers to ensure that the defences are incorporated into redevelopment proposals.

BCC may wish to consider developing future planning policies to safeguard land for future phases of work.

Other mitigation and planning considerations for site specific applications include:

- Considering the characteristics of a possible flood event, e.g. the type and source of flooding and frequency, depth, velocity and speed of onset
- Ensuring safe access and egress
- Resident awareness and flood warning and evacuation procedures

5 SUMMARY

The model runs undertaken during the latest phase of work (preferred options refinement stage) have significantly improved the understanding of residual risk. However, whilst some targeted modelling runs have been undertaken (breach runs and overtopping / overflow flood events), the risk has not been assessed via an extensive suite of modelling runs. More model runs could be undertaken in future work should a more detailed understanding of residual risk be required.

Information from the Strategy will feed in to updated versions of the Joint Spatial Plan / Bristol Local Plan. In addition it would be appropriate for BCC strategic planners to review the findings of the above design standard event modelling results and breaching results with respect to existing and future site allocations.

It may be necessary for developers to undertake additional measures to reduce the consequences of flooding to developments and the local plan refresh, due in 2019 should include requirements for future development to mitigate residual risk.

Implementation of the Strategy will reduce the dominant source of risk (tidal flooding) and it will also reduce secondary fluvial flood risk (although the Strategy has not quantified the additional fluvial benefits); this will help reduce the scale of site specific mitigation required; however it has been demonstrated that there will still be a requirement for suitable site measures to mitigate residual risks. For example the following types of measure may need to be implemented:

- innovative non-residential street scape solutions to flood routeing and storage
- floor level and threshold raising
- sustainable drainage
- on-site defences
- safe access and egress provisions
- emergency warning and evacuation procedures.

Planning policy and development control procedures will then need to be updated as appropriate to ensure that the suitable mechanisms are in place to manage and reduce these on a site-by-site basis.