



Initial assessment report

Worth Village

November 2016

Using this template

The standard headings and tables in this template should be modified to meet the requirements of each Initial Assessment. The sites may have diverse issues and constraints and problems and the standard template is therefore just a guide on typical requirements but flexibility is allowed to amend/ add headings as required

Hidden guidance

The template contains various pieces of guidance covering content, use of tables etc. The guidance is shown in **blue text** and can be turned 'on' to assist in the writing stages or 'hidden' for viewing or when printing the document. You can switch between 'hidden' and 'on' and back to 'hidden' at any time.

To show/hide the guidance click on the ¶ icon on the MS Word toolbar.

If the hidden text does not disappear off the screen when the ¶ icon is clicked, go to: Tools>Options>View Tab and uncheck the 'Hidden text' box.

It is advisable to work with the hidden text turned on, as this helps to format new text and to avoid deleting the hidden text itself.

Inserting new headings

To insert new headings in the main text go to: Format>Styles and Formatting to open the styles box. Insert the new headings, highlight it and click on the appropriate Heading level in the 'Pick formatting to apply' box. Paragraph text can be inserted and formatted in a similar way.

Inserting new tables

Table labels should be added by Insert>Reference>Caption and selecting 'Table' from the drop down 'Label' box. This will insert the Table title with the correct number and the caption can be typed in after the label. Tables can then be cross referenced from the text by Insert>Reference>Cross Reference and selecting the appropriate reference type and caption from the drop down box and list.

Numbering paragraphs

All paragraphs should be numbered sequentially as sub-sets of the section number. Prompts for paragraph numbering are provided as 'Start writing here' after which pressing <return> will automatically provide the next paragraph number.

1 Initial Assessment Report

Scheme or project location name	Yorkshire Area Initial Assessments: Worth Village
---------------------------------	--



Riverside in Worth Village during the 2015 Boxing Day flood incident

Date	November 2016
Version	1.0

Version control

Version	Status	Signed off by:	Date signed	Date issued
0	Draft	G Fardell	21.09.16	21.09.16
0.5	Final	G Fardell	21.10.16	21.10.16
1.0	Final			
2.0	Final	EA	05.12.16	05.12.16

Contact Details

Role	Name	Post Title
Project Sponsor		
Senior User		
Senior Supplier	Richard Crowder	
Project Executive	Paul Stainer	
Project Manager	Glenn Fieldhouse	

Sign Off

Form completed by:	Name:	Title: Project Manager	Signature:	Date:
Project Executive Approval:	Name:	Title: Project Team Leader	Signature:	Date:
Senior User Approval:	Name:	Title:	Signature:	Date:
Project Sponsor Approval:				

CONTENTS

1	INITIAL ASSESSMENT REPORT	II
1.1	Introduction and background.....	3
1.2	Problem and objectives.....	6
1.3	Benefits.....	7
1.4	Options	7
1.5	Initial environmental assessment	23
1.6	Consultation.....	24
1.7	Economic summary and preliminary preferred option.....	Error! Bookmark not defined.
1.8	Project Scoring.....	28
1.9	Further work requirements	30
1.10	Conclusions and Recommendation.....	30
Table 1.1	Potential storage areas identified on the River Worth and its tributaries	16
Table 1.2	Options taken forward for assessment	21
Table 1.3	Project initial costs and annual maintenance (£k)	22
Table 1.4	Key environmental impacts, mitigation and opportunities	23
Table 1.5	Number of Properties at Risk (based on current outlines and SOP of existing schemes)	24
Table 1.6	Benefit-cost assessment	Error! Bookmark not defined.
Table 1.7	Outcome measures and Partnership Funding Score	26
Table 1.8	Risks and mitigation	28

APPENDICES

Appendix A	Site visit Report
Appendix B	Option cost details
Appendix C	Benefit details
Appendix D	Economic appraisal
Appendix E	Funding calculation sheets
Appendix F	Constraints Table
Appendix G	Location Maps

1.1 Introduction and background

1.1.1 Description of Location

This assessment looks at the Worth Village area of Keighley within the Bradford Metropolitan area in West Yorkshire. The River Worth flows through Worth Village to its confluence with the River Aire at Stockbridge. The study area covers the River Worth from the railway bridge close to Keighley Station to its confluence with the River Aire and the area along the Aire protected by the Stockbridge flood defences. This area was identified as it was severely flooded during the Boxing Day 2015 flood incident.

The study area lies within the 30% most deprived areas in the country with a majority of the site in the most deprived 10%.

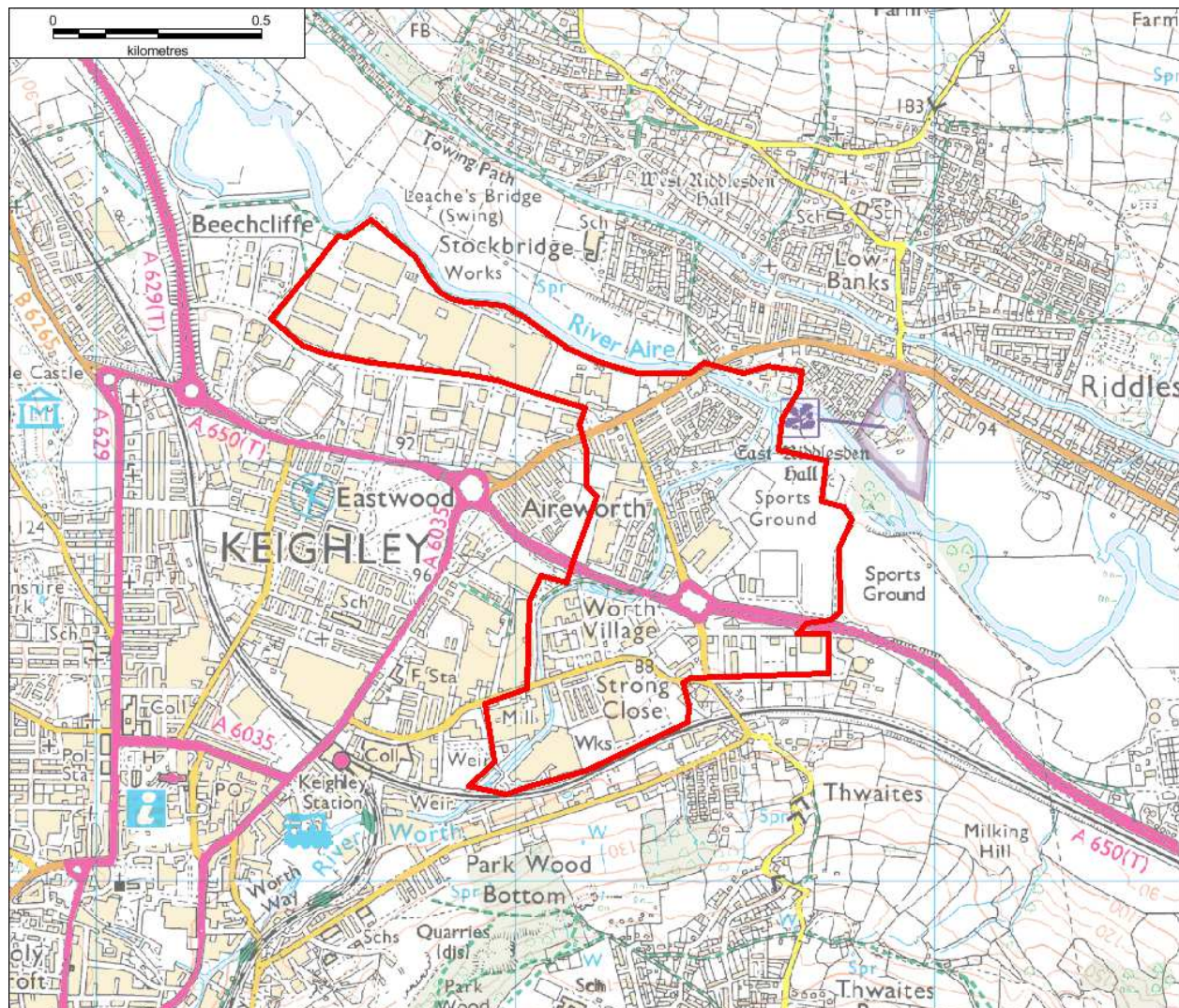


Figure 1: Location of Study Area

1.1.2 Description of Watercourses and Geology

There are two rivers within the study area; the River Aire flowing west to east and the River Worth flowing south to north. Both are classified as Main Rivers.

The River Aire is a major river in Yorkshire flowing from Malham in the Yorkshire Dales, through the urban areas of Bradford and Leeds, before joining the River Ouse at Airmyn. The Aire is approximately 71 miles in length from its source to its confluence.

The Upper Aire around Bradford is heavily urbanised and the floodplain is constrained by development. There is also a large number of structures such as bridges in this area.

The River Worth is a large tributary to the Aire and flows north-east from its source near Oxenhope through Haworth to Keighley where it joins the River Aire. The river is approximately 4.1 miles in length from its source to the confluence with the River Aire. The upper reaches of the river are rural before the river passes through the urbanised areas of Keighley. This area of the catchment is highly urbanised and can react quickly to heavy rainfall.

There are a number of tributaries of the River Worth upstream of the study area including North Beck and Bridgehouse Beck.

There are two defence schemes within the study area:

- The Stockbridge scheme constructed along the River Aire from the commercial properties on Royd Ings Avenue to the confluence with the River Worth. This provides a standard of protection (SOP) with 1 in 100 (1%) Annual Exceedance Probability (AEP) each year following reinstatement of these defences after a flood incident in 2000.
- The River Worth Flood Alleviation scheme constructed along the River Worth from the railway bridge to its confluence with the River Aire. This scheme was constructed in the late 1980s to provide a 1 in 50 (2%) AEP standard of protection. Due to deterioration of the River Worth scheme it is thought that the SOP currently provided is less than its design level.

1.1.3 History of Flooding

The study area is prone to flooding and there have been a number of historical incidents. There were recent flood incidents in 2000 and 2004. Major historical incidents occurred in 1866 and 1946.

The 2000 flooding was driven by the River Aire. This event caused widespread flooding throughout the Aire catchment. During this incident the Stockbridge defence scheme was breached causing major flooding to the north of the study area. The defence scheme was reinstated following this event.

The 2004 flooding was driven by the River Worth. This incident caused flooding throughout the Worth catchment including Worth Village.

The study area was flooded in Winter 2015/16 with the most severe flooding occurring on Boxing Day, when there was widespread flooding along the River Aire. This 2015 event was the largest recorded event on the River Aire. This event was estimated to have a return period between 80 and 100 years on the River Aire upstream of Keighley at Kildwick. This was caused by a wet November saturating the catchment followed by heavy rainfall on the 25th and 26th of December as a result of Storm Eva.

Within Worth Village the main sources of flooding on Boxing Day 2015 were from the River Worth and from surface water. A large number of properties within the study area were affected. Areas along the River Worth were flooded as the river overtopped its channel.

The north area of the town at the confluence of the Rivers Aire and Worth was flooded from surface water. This area is protected by flood defences but flooded when the drainage network was unable to discharge into the River Eden.

An area of Worth Village was flooded due to a gap in the flood defences caused by the demolition of a structure along the defence line at Dalton Mills. This has since been addressed with a temporary defence structure as part of recovery work.

Following the Boxing Day 2015 flood incident surveys of the area have shown numerous cracks, gaps and holes in defences along both rivers. In addition to this there are a number of locations where major defects in walls have been identified with these walls at risk of collapse. Structural assessment of walls has been undertaken in several locations.

There has been significant emergency maintenance work since the winter 2015/16 flooding, with critical repairs undertaken to defences identified as damaged. There has also been gravel removal from the river throughout the study area to remove accumulation that occurred during the high flows.

1.1.4 Summary of Previous Modelling Analysis

Aire

In 2008 hydraulic and hydrological modelling of the Upper River Aire was completed by JBA to support the development of the Flood Risk Management Strategy. For this study the River Aire was modelled from High Hill Weir upstream of Gargrave to Fleet Weir downstream of Leeds. The Upper River Aire model is a 1D hydrodynamic ISIS model containing 1922 nodes.

The 2008 modelling study aimed to define flood risk within this area and identify potential flood risk management options. This informed the Flood Risk Management Strategy for the Upper Aire. This strategy recommended local flood risk management schemes where there is a justification for this and identified a number of sites that should be progressed. It was recommended that schemes along the River Worth were investigated in the medium term and raised defences at Stockbridge in the longer term.

Worth

A Hydraulic model of the River Worth was developed as part of the River Worth 2007 SFRM study. This model has since been updated to better account for existing defences and converted to a 1D/2D model.

Recommendations from the 2007 study included assessment of the condition of 3rd party walls in Worth Village and investigating potential upstream storage on the River Worth. Other recommendations outside of Worth Village included upstream storage on North Beck and investigations into raising culvert capacity on North Beck and Bridgehouse Beck.

Recalibration of the River Worth model is currently ongoing to ensure the model is up to date and accurately reflects the 2015 Boxing Day event. This will update the flood risk mapping to include new data collected during the 2015 flooding.

From these studies modelled flood outlines are available for the study area for 25, 50, 75, 100, 200 and 1000 year return periods showing properties at risk from flood incidents of these magnitudes. The areas that benefit from the two defence schemes are also identified. A map of flood risk and areas benefiting from defences is included in Appendix G.

1.1.5 Drivers, Constraints, Opportunities

The study area falls under the River Aire Catchment Flood Management Plan (CFMP)¹, and is covered by sub-area 3 - Worth and Aire. The designated policy for the area at risk is Policy Option 5: Areas of moderate to high flood risk where we can generally take further action to reduce flood risk.

The following drivers, constraints and opportunities have been identified within the study area:

Political Drivers	Summary Description
Catchment Flood Management Plan	Aire CFMP 2010
Catchment Flood Management Policy	Policy 5 – Areas of moderate to high flood risk where we can generally take further action to reduce flood risk.
Economic Drivers	Summary Description
Reduced Maintenance Costs	Maintenance costs of the River Worth scheme can be reduced through alternative management of gravel build-up
Funding Time Constraints	Must be obtained within 6 year programme of capital

¹ River Aire Catchment Flood Management Plan <https://www.gov.uk/government/publications/river-aire-catchment-flood-management-plan>

	investment
Social Drivers	Summary Description
Improvements to Social Deprivation	Large areas of the site are within the 10% most deprived neighbourhoods in the UK
Technological Drivers	Summary Description
Improved Public Safety	Via reduced flood risk
Improved Maintenance	Maintenance costs of the River Worth scheme can be reduced especially through alternative management of gravel build-up
Environmental Constraints	Summary Description
Sites of Special Scientific Interest (SSSI)	South Pennine Moors SSSI 1.7 km north of the study area
Special Area of Conservation (SAC)	South Pennine Moors 1.7 km north of the study area
Ancient Woodland	Ancient woodland 0.2km north of study area
Tree Preservation Orders	There are three groups of protected trees alongside the watercourse within the study area
Listed Buildings	9 listed buildings within the study area including Aireworth Mill and Dalton Mill along the River Worth

Refer to Appendix F for the full list of constraints that were considered.

1.2 Problem and objectives

1.2.1 Problem

The site is at risk of fluvial flooding from the two rivers. There is also a risk of surface water flooding caused by high river levels preventing the drainage system discharging.

The main cause of flooding in the Boxing Day 2015 flood incident was the River Worth. There are defences along this river providing a 1 in 50 (2%) AEP Standard of protection. There are also areas of the town along the Worth not protected by formal flood defences. In these areas 3rd party walls act as flood defences providing some protection from flooding.

The Worth Village Flood Alleviation Scheme (FAS) was constructed in the 1980s and requires significant repair and replacement due to deterioration of these assets and the 3rd party walls along the channel. There is a significant risk of defences collapsing and it is thought that the current standard of protection provided by the scheme is below the 1 in 50 (2%) AEP design level.

It is currently planned to replace this scheme in 2034 at the end of its design life. However, properties are currently at a greater risk of flooding than would be expected with the scheme in place and this risk will increase with further deterioration or failure of the scheme.

The Stockbridge FAS provides protection to the north of the study area from flooding from the River Aire. These defences provide a 1 in 100 (1%) AEP standard of protection and were not overtopped in the Boxing Day 2015 flood incident. However, there remains a risk to the area of flooding from the River Aire.

The north of the study area is at risk of surface water flooding. There was significant flooding from this source in the area during the Boxing Day 2015 event. This was caused by high river levels preventing the drainage network from discharging into the River Aire. There was also groundwater flooding reported in this area.

1.2.2 Objectives

The primary objective of this initial assessment is to identify if there is potential for justification of an improvement scheme to reduce flood risk and to recommend if appraisal should progress to development of an Outline Business Case. This includes a review of flood risk in the area and scoping of possible flood risk management measures for the affected properties which are consistent with the current CFMP policy.

The purpose of this report is to lay the groundwork and, where applicable, provide a business case for undertaking more detailed future appraisal. The report aims to achieve the following:

- Confirm the need for a project;
- Identify the issues and Political, Environmental, Societal, Technological, Legislative and Economic (PESTLE) drivers and opportunities related to the need;
- Identify the options to address the need and problem;
- Demonstrate that viable options exist based upon the available information;
- Provide input into the identification and estimation of efficiencies;
- Provide sufficient information to allow the packaging and optimisation of packages of future appraisal, design and construction packages;
- Provide sufficient information for the appraisal scope to be prepared;
- Make an assessment on the deliverability of the project;
- Provide a basis/starting point for discussion with communities and partner organisations for use in the development of potential schemes and negotiations regarding funding contributions.

1.3 Benefits

In this area the primary benefit associated with a reduction in flood risk would be the reduction in economic damages to properties. This in turn will reduce disruption to local transport, businesses, schools and other infrastructure. The main beneficiaries will be properties already protected by the two defence schemes. The properties at risk are residential and commercial properties. There are no significant public buildings within the study area. Social benefits relate primarily to a reduction in stress, health effects (including risk to life) and loss of memorabilia for those at risk.

Through changes to the management of gravel within the River Worth there are expected to be benefits from alternative maintenance. This will reduce both the costs of maintenance and the disruption to the area associated with carrying this out.

An appraisal period of 100 years is assumed based on FCERM appraisal guidance and the expected lifespan of new assets. Two standards of protections are considered; 1 in 100 (1%) AEP with climate change and 1 in 200 (0.5%) AEP with climate change. This ensures that the options considered will provide a good level of protection throughout the appraisal period. The standard of protection provided will decrease over time due to climate change.

1.4 Options

A long list of options has been compiled for the study area and is summarised in the table on the following pages. The table shows the range of options considered and the reasoning for or against taking these forward to the shortlist of options assessed.

Category	Long List Option	Source of Flooding Reduced	Take Forward for assessment?	Description / Reasoning
Do nothing	Do nothing	None	Yes	All operational and maintenance activities cease This is not seen to be a viable option but is required to support development of business case and benefit cost ratios.
Do minimum	Do Minimum	All	Yes	Continue with current operational and maintenance activities Required to support development of business case and incremental b/c ratio. This includes reactive repairs to the River Worth FAS but not major investment. As such the condition of this scheme will continue to deteriorate.
Non-structural (by EA)	Improved flood warning	Fluvial (Aire and Worth)	No	Enhanced flood warning to allow residents to prepare plus appropriate implementation of flood action plans This is not funded via the capital programme. This is already a flood warning system is already in place for the River Worth and improving the current system would require further modelling which is beyond the scope of this study.
Non-structural (by EA)	Flood action plans	All	No	Improved direction of reactionary flood defence measure (fire crews, temporary pumps, etc.) This option is not funded via the capital programme. It is recommended to continue to work with local flood action groups.
Property level protection	Property level protection	All	No	Protection to individual properties (e.g. via air brick covers, door guards etc.) There are a large number of properties at risk. Property level protection is therefore unlikely to be viable solution for the entire study area.
Operational (by Others)	Improve operation/design	Fluvial (Worth)	No	Flood risk management through operation of reservoirs Upstream of Keighley there are 3 Yorkshire Water Services (YWS) reservoirs on the River Worth and its tributaries. These are Leeming Reservoir, Lower Laithe Reservoir and Ponden Reservoir on Bridgehouse Beck, North Beck and the River Worth respectively. Use of these to store flood water would reduce risk to Keighley. These sites were not identified as having significant potential for flood management following assessment by the Environment Agency. This option has not been considered within this report.

Category	Long List Option	Source of Flooding Reduced	Take Forward for assessment?	Description / Reasoning
				Further assessment of the technical feasibility and costs of using these reservoirs would require detailed consultation with YWS that has not taken place at this stage. It is thought that construction of a new upstream storage area will be more beneficial than use of existing reservoirs.
Operational (by Others)	Improve operation/design	Surface Water	No	<p>Flood risk management through operation of sewage network</p> <p>It was identified that there may be potential to work with Yorkshire Water to manage surface water flooding in the area.</p> <p>There are existing sewage interceptor tanks within football grounds near Surrey Street. These tanks were constructed to alleviate flooding from sewers to nearby properties.</p> <p>This has not been taken forward for further appraisal but should be considered in future assessment of risk of surface water flooding.</p>
Urban drainage	Improve urban drainage	Surface Water	Yes	<p>Improvements to surface water drainage system</p> <p>Surface water drainage could be improved by installation of permanent pumps at Florist Street to enable surface water to discharge into the River Aire during high river levels.</p> <p>During the Boxing Day flood event the area around Florist Street was flooded by surface water as the drainage system was unable to discharge into the Aire.</p> <p>The current outfall was identified as a suitable location to install pumps.</p>
Structural	Earth bunds	N/A	No	<p>Construction of flood bunds</p> <p>There is insufficient space available within urban area to construct earth embankments.</p>
Structural	Flood walls	Fluvial (Worth)	Yes	<p>Reinstate/Raise River Worth scheme</p> <p>This option immediately replaces the River Worth FAS and raise defences to increase the standard of protection provided.</p> <p>The scheme is currently in poor condition and needs significant repair</p>

Category	Long List Option	Source of Flooding Reduced	Take Forward for assessment?	Description / Reasoning
Structural	Flood walls	Fluvial (Aire)	Yes	Reinstate/Raise Stockbridge scheme This option replaces the Stockbridge FAS and raises defences to increase the standard of protection provided.
Structural	Improvement of 3 rd Party defence assets	Fluvial (Worth)	Yes	Improvement of defence assets not owned by the EA Informal defences along the River Worth have been identified as being in poor condition with significant risk of failure. Working with landowners to manage the condition of these assets or replace them with formal defence assets would reduce the risk associated with failure of these defences and increase the area protected by the River Worth FAS.
Structural	Temporary defences	N/A	No	Demountable flood walls, flood gates etc. The catchment is seen to respond rapidly to rainfall. The area at risk is not suitable for deployment of temporary defences as there is not sufficient warning to deploy these.
Structural	Conveyance	Fluvial (Aire and Worth)	No	Channel deepening or widening There is insufficient space to widen the River Worth within the study area. Conveyance of the River Aire not an issue and increasing this would not significantly reduce flood risk. The Environment Agency current undertakes gravel management along both rivers to maintain conveyance.
Structural	Conveyance	N/A	No	Supplementary bypass channels, tunnels or floodway No suitable locations for bypass channels identified.
Structural	Conveyance	Fluvial (Worth)	Yes	River restoration and/or pinch point improvements (bridges, culverts and weirs) Remove 'Ski Jump' weir and replace defence walls at this location. This was recommended from a 2016 Capita AECOM study into maintenance of the River Worth. This option is economically beneficial but does not significantly reduce flood risk. As such this will not address the problems considered. This option has been taken forward in combination with other options.

Category	Long List Option	Source of Flooding Reduced	Take Forward for assessment?	Description / Reasoning
Flood storage area	Online	Fluvial (Worth)	Yes	<p>Use of active structures and re-profiling to store water online (River Worth)</p> <p>Develop online flood storage area upstream of Worth Village on the River Worth and/or its major tributaries.</p> <p>A number of potential sites for upstream flood storage have been identified within the Upper Aire SFRA and by Bradford Metropolitan District Council.</p> <p>Use of these sites would reduce peak flows in Keighley increasing the standard of protection provided by existing defences.</p> <p>This could also potentially reduce flood levels throughout the Worth catchment and downstream of Keighley on the River Aire.</p>
Flood storage area	Online	Fluvial (Aire and Worth) Surface Water	Yes	<p>Use of active structures and re-profiling to store water online (River Aire)</p> <p>The Upper Aire SFRA considered 2 online storage areas at Keighley Holden Park and Marley Bridge. The Holden Park site is upstream of Worth Village and would reduce flood levels in the River Aire within the study area.</p> <p>This would reduce the risk of flooding from high flood levels in the River Aire. Reducing river levels on the Aire would also reduce risk from the River Worth close to the confluence and from surface water where drainage would not be able to discharge into the Aire during high river levels.</p> <p>This area is being investigated for its benefits to Leeds City Centre as part of phase 2 of the Leeds FAS.</p> <p>This storage would also have benefits across the River Aire catchment including the properties at risk in Worth Village.</p>
Flood storage area	Offline	N/A	No	<p>Gravity or pumping to offline storage area</p> <p>No suitable areas identified for offline storage</p>

1.4.1 Shortlisted Options

Do Nothing

The Do Nothing option is defined as taking no action whatsoever; under this option all management activities would cease, including maintenance and repair work to existing assets. The property counts for the Do Nothing scenario have been estimated based on flood extent outlines generated by hydraulic modelling.

For this option the assumption has been made that the River Worth defences have failed and provide no reduction in flood risk.

Do Minimum

The Do Minimum option assumes continuation of the existing maintenance regime. This includes maintenance requirements for existing structures and assets, channel maintenance, operation and maintenance of weirs and other in-channel structures and where possible, existing non-structural measures such as flood forecasting and flood warning.

In this scenario repairs are carried out to the River Worth FAS and maintenance is carried out to prolong the assets lifespan. Despite this, the scheme will continue to deteriorate and eventually fail. Following this failure the scheme will provide no benefit and the damages in this scenario will be the same as the Do Nothing option.

The disadvantage of the Do Minimum option is that properties will remain at risk prior to the scheme replacement due to the poor condition of the scheme and the risk of breaches.

This is viable as an option in the near-future but will become unviable once the scheme fails. After year 20 damages in this scenario will be the same as the Do Nothing scenario and there will be no benefit from the scheme.

Reinstate River Worth FAS / Raise Defence Levels

The River Worth FAS was constructed in the 1980s and is currently in poor condition. This scheme was also designed to provide a relatively low standard of protection (1in50 2%AEP).

Reinstating this scheme and rebuilding the defences to a higher level will reduce the risk of flooding from the River Worth. The alignment of the scheme is not expected to change; as such this option will only benefit the areas that benefit from the existing scheme.

As this option follows the alignment of the existing defence scheme this will reduce the usual impacts and risks of wall construction. The new walls would need to fit the character of the existing area. There would be a visual impact from increases in the height of the walls.

The defence scheme is located along the river and close to properties. As such there will be technical challenges with work to this scheme. This, as well as the visual impact of the wall, will limit the level to which this wall can be raised.

Three Levels of Reinstatement are considered:

- Reinstatement to existing level 1in50 (2%) SOP

This will carry out repairs to the scheme to address the risk of the scheme failing. The defences remain at the existing level, it is therefore seen that there is no long-term impact on the environment.

Properties protected by this scheme will remain at risk from a 1in50 (2%) AEP flood incident. This level of protection will also decrease over time due to climate change.

As this option follows the alignment of the existing defence scheme this will reduce the usual impacts and risks of wall construction. The new walls would need to fit the character of the existing area.

- Reinstatement to 1in100 (1%) SOP including climate change

This option raises the scheme to maintain a 1in100 (1%) SOP throughout the appraisal period including the impacts of climate change. The standard of protection provided would be greater than 1in100 (1%) following construction of this option and this would decrease over time due to climate change.

The estimated increase in defence heights are expected to be between 0.35m and 0.6m. This would need to be assessed through hydraulic modelling to confirm the increase in heights required.

The scheme is close to the river and to properties and there will be high costs associated with raising the level of these defences due to technical challenges with accessing this area and increasing the footprint of defences. The raised defences will also have an increased visual impact on the surrounding area.

- Reinstate to 1in 200 (0.5%) SOP including climate change

This option raises the scheme to maintain a 1in200 year (0.5%) throughout the appraisal period including the impacts of climate change. The standard of protection provided would be greater than 1in200 (0.5%) following construction of this option and this would decrease over time due to climate change.

The estimated increase in defence heights are expected to be between 0.55m and 0.95m. As with the 1in100 (1%) SOP this would need to be assessed through hydraulic modelling to confirm the increase in heights required.

As this increase in height is greater than for the 1in100 (1%) SOP there will be greater impacts, costs and challenges with this construction. It may not be practical to construct defences to this level in some areas of the scheme.

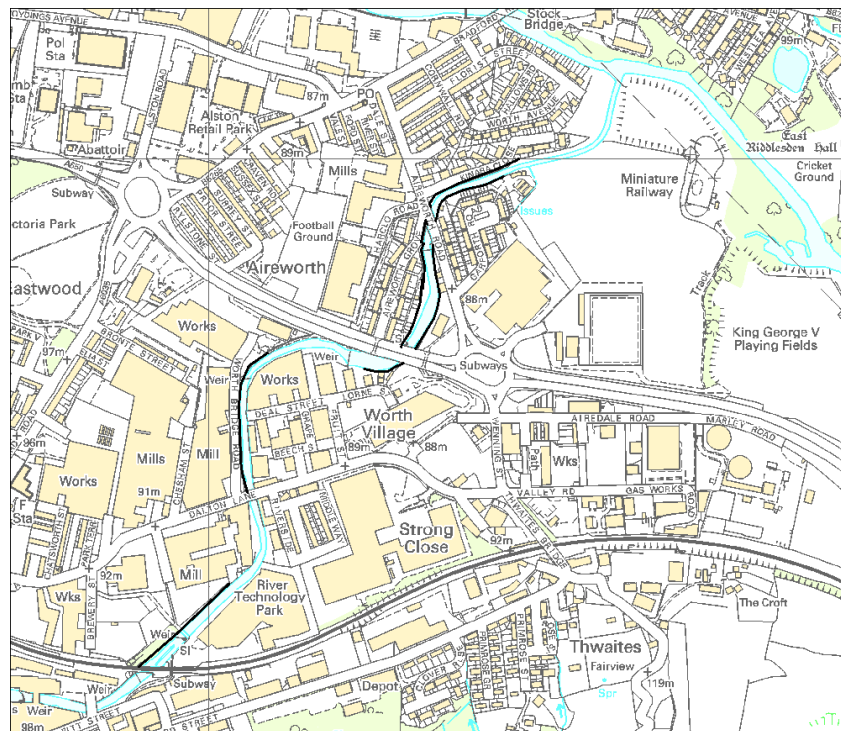


Figure 1a: Existing line of the Worth Defences

Raising the defences to a 1in100 or 1in200, including climate change, SOP is thought to have a high cost and would be technical challenging. Reinstatement of the defences to a lower level in combination with other options such as upstream storage may be a more cost-effective solution to provide a similar SOP.

In order to further assess this option modelling of the proposed defence alignment would need to be undertaken to determine the level of defences required to provide a higher standard of protection. This would allow the impact of the defences upstream and downstream of the scheme to be assessed to ensure there is no increase in flood risk. Ground investigation and analysis of the current defence alignment would also need to be undertaken in order to assess the technical viability of constructing defences to a higher level.

Replace third party walls within Worth Village with formal flood defences

Several areas in the study area along the River Worth are not protected by formal flood defences. Third party walls provide some defence to these properties but these have been identified as being in poor condition. Properties protected by third party walls will not benefit from improvements to the River Worth FAS.

Repairs to these walls and replacement of these with formal flood defences would increase the protection provided to properties within the town. This would reduce the risk associated with walls breaching and provide a more consistent standard of protection throughout the town. This option increases the area of the town protected by the River Worth FAS. The areas benefiting from this would primarily be commercial and industrial properties.

This would require consultation with riparian landowners in the area. The condition of existing walls and the level of protection provided by these would need to be assessed to determine the amount of replacement required and the current risk to the area.

For the options assessment, it is assumed that 50% of the walled channel within Worth Village that is not protected by formal defences is replaced with walls similar to those in the defence scheme. This requires the construction of 460m of reinforced concrete walls.

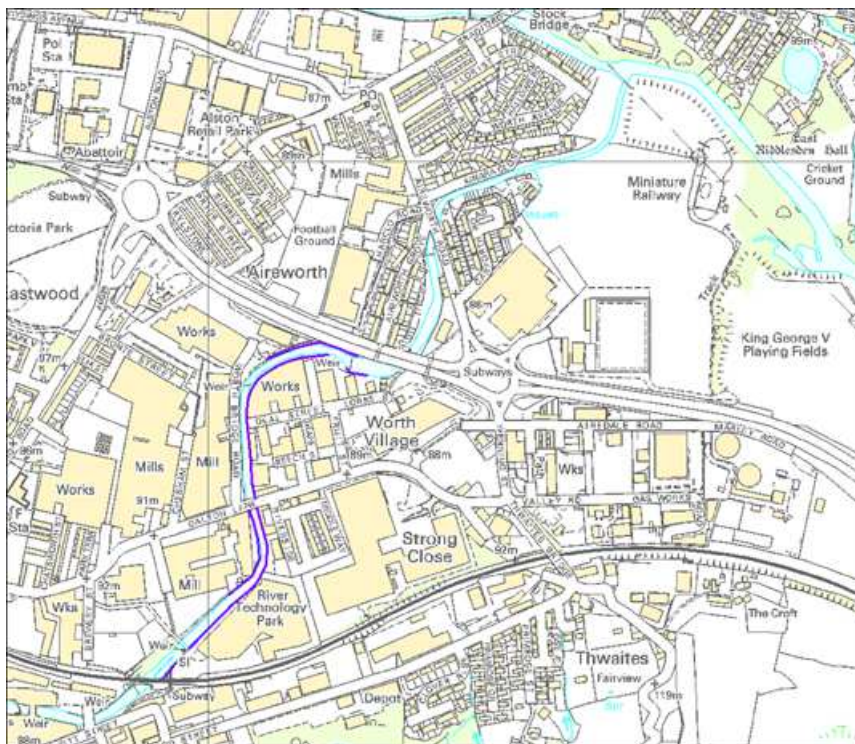


Figure 1b: Third party walls to be replaced with formal defences

Removal of Ski Jump Weir

A previous study carried out by Capita AECOM in 2016 assessed the management of gravel build-up at Aireworth Road Bridge. The current process for managing gravel involves disruptive road closures to lift equipment into the channel and has a high cost.

This report recommended alternative maintenance using a suction vac. This also included construction of access routes to the river to facilitate this maintenance. This improved management of gravel would reduce flood risk in the area.

This report also recommended the removal of the 'Ski Jump' weir upstream of Aireworth Road Bridge. Removing the weir is beneficial due to the cost of ongoing maintenance of the asset

which is in poor condition. This asset has limited benefit for gravel management. Removing the weir also provides a small reduction to flood risk and has ecological benefits.

There will be a cost saving from implementing the recommended options from this report alongside other work within Worth Village. This will not significantly reduce flood risk but can be carried out in combination with any of the other options considered.

Reinstate Stockbridge FAS / Raise Defence Levels

The Stockbridge FAS defends the north of the study area from flooding from the River Aire. This scheme was reinstated in 2000 and currently provides a 1in100 year (1% AEP) standard of protection. Raising this scheme will reduce the risk of flooding from the River Aire.

It is assumed that the existing defences are in reasonable condition and will continue to provide the current level of protection with ongoing maintenance. The standard of protection provided will decrease over time due to climate change.

A majority of the residential properties protected by this scheme are also at risk from the River Worth. As such raising this scheme has limited benefits without also reducing the risk of flooding from the Worth.

As with the Worth FAS the impacts of raising this wall will be reduced due to following the alignment of the existing defences. The walls would have a visual impact due to the higher levels of defences. The current defences are along property boundaries and would require consultation with landowners. As the defences are close to properties and to the river there will be technical challenges in working on these defences and to raising the level of protection provided.

As the existing defences are thought to be in reasonable condition it may be possible to raise the level of the existing assets rather than replacing these. If this is feasible it would reduce the costs of increasing the level of defences.

Two levels of reinstatement are considered:

- Reinstatement to 1in100 (1%) SOP including climate change

This option raises the scheme to maintain a 1in100 (1%) SOP throughout the appraisal period including the impacts of climate change. The standard of protection provided would be greater than 1in100 (1%) following construction of this option and this would decrease over time due to climate change.

The estimated increase in defence heights is expected to be 0.8m. This would need to be assessed through hydraulic modelling to confirm the increase in heights required.

- Reinstatement to 1in200 (0.5%) SOP including climate change

This option raises the scheme to maintain a 1in200 (0.5%) SOP throughout the appraisal period including the impacts of climate change. The standard of protection provided would be greater than 1in200 (0.5%) following construction of this option and this would decrease over time due to climate change.

The estimated increase in defence heights is expected to be 1.2m. This would need to be assessed through hydraulic modelling to confirm the increase in heights required.

In order to further assess this option modelling of the proposed defence alignment would need to be undertaken to determine the level of defences required to provide a higher standard of protection. This would allow the impact of the defences upstream and downstream of the scheme to be assessed to ensure there is no increase in flood risk. Ground investigation and analysis of the current defences would also need to be undertaken in order to assess the technical viability of raising defences.

Installation of Permanent Pumps at Florist Street

The area surrounding Florist Street is affected by surface water flooding when the drainage system near the confluence of the Rivers Aire and Worth cannot discharge into the Aire when river levels are high. At this point, water collects on the dry side of the flood embankment along

the river Aire. This location was identified as suitable for a pumping station. This area is not accessible during a flood incident so it is not possible to use temporary pumps.

These pumps will require maintenance. As this is an active structure there would also be an ongoing operational cost and a relatively high lifetime carbon cost. There is also a risk of pump failure during a flood event.

As these pumps primarily manage surface water risk it would need to be determined which authority manages and operates the pumps. This appraisal includes the operation and maintenance costs in order to determine if installing these pumps is economically viable.

This only benefits the northern extent of the study area and does not significantly protect against flooding from overtopping of defences. Installation of these pumps would need to be undertaken in combination with works to address fluvial flooding.

Modelling of the surface water risk in the area would need to be undertaken in order to identify the properties at risk and level of benefit from these pumps. This would also require consultation with Bradford MDC to determine responsibility for operation and maintenance of the pumps.

Upstream Flow Attenuation on River Worth

Several potential storage sites have been identified on the River Worth and its tributaries. These are shown in the plan in Appendix G. These have been identified from the 2014 Upper Aire SFRA and from discussion with Bradford MDC. Use of a storage site would reduce peak flows in Keighley increasing standards of protection provided by the River Worth defences as well as increasing the level of protection provided by third party walls.

This is a permanent defence solution that does not reduce the capacity of the stream and increases connection between the river and the floodplain. There is a requirement to negotiate use of the storage area with landowners. There will also be costs associated with operation and maintenance of the area.

Table 1.1 shows the potential locations considered; approximate locations of these are shown in Figure 2:

Table 1.1 Potential storage areas identified on the River Worth and its tributaries

Location	Watercourse	NGR	Comments
Damens Road	River Worth	SE052391	93,100m ² area Estimated land costs of £360k
Bronte Caravan Park	River Worth	SE045384	331,800m ² area Largest storage area but thought to be unviable due to high cost of land purchase (£3m+) due to the caravan park.
Grey Scar Road	Providence Lane	SE024388	52,600m ² area Estimated land costs of £100k-£175k
Lord Lane	River Worth	SE028378	Estimated volume of 460,000m ³ Thought to be unsuitable as would require use of a very large area upstream in order to comply with reservoir regulations. Upper Aire modelling report estimated this could lead to 50mm reduction in peak levels within Leeds City Centre.
Lumbfoot Road	River Worth	SE014375	Estimated volume of 133,000m ³

Damens Lane	River Worth	SE050387	Estimated volume of 130,000-260,000m ³ depending on depth
Fallow Lane	North Beck	SE023405	Estimated volume of 47,000m ³ Disregarded in Upper Aire modelling report as would have minimal effect on levels in the River Aire

The options assessed in this report consider the use of Damens Road and Grey Scar Road sites as estimated costs of these have been produced by Bradford MDC. It is recommended that further assessment of upstream storage on the River Worth should consider the other sites in more detail.

The volume of water stored will be greater than 10,000m³. As such the storage area would be considered a reservoir under the 1975 Reservoir Act and reservoir safety would need to be considered in the design and operation of this storage area.

This option will reduce flood risk throughout the River Worth catchment including areas outside of this study area. This option also provides a reduction in flood risk from the River Aire further downstream. The SFRA estimated the use of the Lord Lane storage area could potentially result in a 7% reduction in peak Aire flow and a 50mm reduction in flood depths in Leeds. The Upper Aire SFRA only considered flood risk on the Aire and did not assess the reduction in flood risk from the River Worth or to Worth Village.

For this study this option will be assessed based on its reduction to flood risk from the River Worth in Worth Village. However the benefits of this storage area will be greater than this estimate as there will be a reduction in flood risk beyond this study area.

This option could be undertaken in combination with any of the other options considered and would increase the standard of protection provided by defences. Alternatively defences could be constructed to a lower level to provide the same standard of protection.

Further work to assess these storage areas would need to consider benefits throughout the Worth catchment and downstream on the Aire. The technical and environmental constraints of the storage will need to be assessed to determine if it is feasible to use these. This would also require hydraulic modelling to assess the level of protection provided by the storage area.

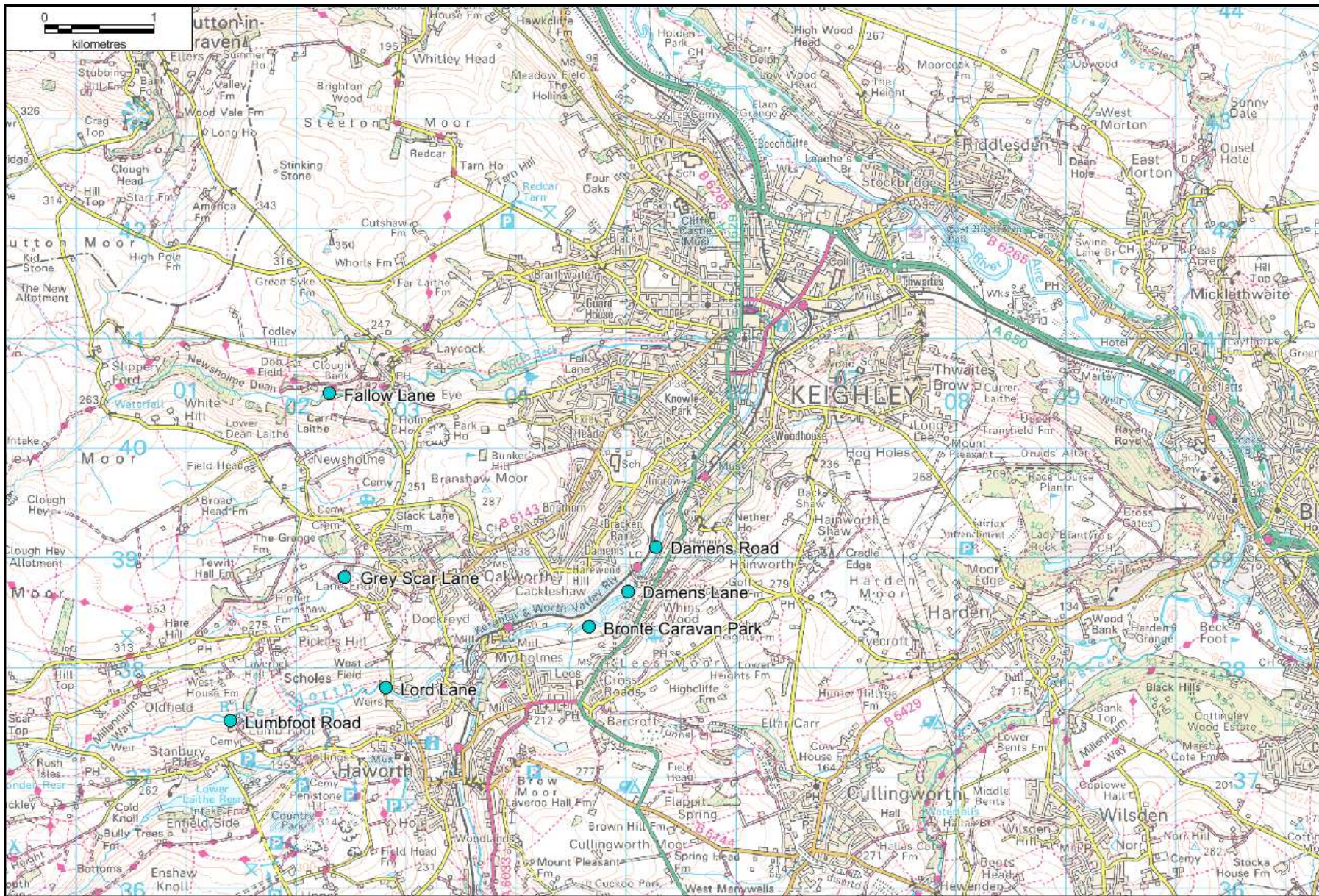


Figure 2: Potential Upstream Storage Areas on River Worth and its tributaries

On-line Storage on River Aire

The modelling carried out to support the Upper Aire SFRA tested a number of on-line flood storage areas (FSA). Two of these were found to lead to significant reductions in flood risk. These sites are Keighley Holden Park and Marley Bridge. Holden Park is the larger of these sites.

The Holden Park site is upstream of Worth Village. As such use of this FSA would reduce flood risk from the River Aire at this site. This site is close to Keighley and as such leads to large reductions in flood levels in the study area. The location of the Holden Park site and Worth Village study area are shown in Figure 3.

This FSA was assessed for a 1 in 100 (1%) AEP flood incident and were estimated to reduce flood levels by 1.07m at Stockbridge. There are also benefits across the River Aire downstream with an estimated reduction in flood levels of 0.31m in Leeds City Centre (greater when combined with the Marley Bridge site).

This storage area could be implemented alongside the other options considered. Use of this storage area would increase the standard of protection provided by the Stockbridge Defence Scheme. This would reduce the requirement to raise the level of this scheme.

The reduction in flood levels on the River Aire from this option will also reduce risk from surface water flooding and fluvial flooding from the River Worth. The main cause of surface water flooding in this area is when the drainage network cannot discharge due to high river levels in the Aire. Reducing levels in the Aire will also reduce levels in the Worth and hence reduce flood risk close to the confluence.

These FSAs have been considered primarily for their benefit in reducing risk to Leeds City Centre and are to be assessed as part of modelling work for phase 2 of the Leeds FAS. However they will provide benefits to areas along the River Aire downstream of the FSA.

This initial assessment considers the Worth Village area. Whilst the FSA upstream of here would reduce risk to Worth Village it will have significant benefits beyond the study area. As such assessing the benefits and costs of this option are considered to be outside of the scope of this study and this has not been assessed.

Further work to assess these storage areas would need to consider benefits across Bradford and Leeds and assess the costs and impacts of using the land as a storage area. This would also require hydraulic modelling of the River Aire to assess the level of protection provided by the storage area.

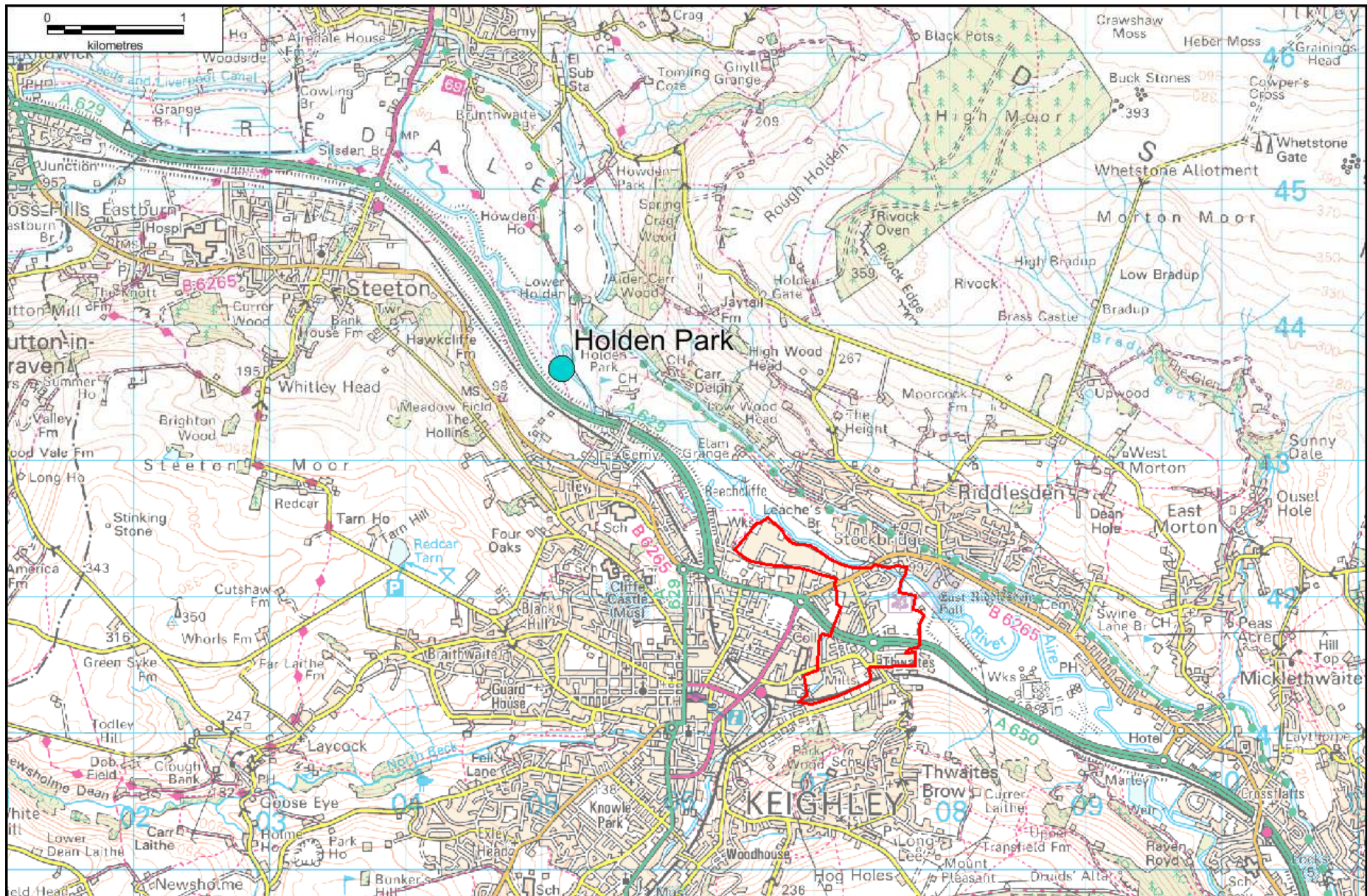


Figure 3: Location of Holden Park Upstream Storage Area on River Aire, Study area in red outline

1.4.2 Options assessed

The area is at risk of flooding from a number of sources; none of the options considered will reduce the risk from all sources. As such the options considered have been combined to form a shortlist of options. These Options are shown in Table 1.3.

The upstream storage area on the River Aire has not been considered. This storage area will have benefits for Worth Village and will increase the SOP provided by the Stockbridge FAS. This is thought to be a preferable solution to provide a 1in200 (0.5%) SOP from the River Aire as raising the defence walls to a high level may be impractical. This FSA will have high costs and would have benefits throughout the River Aire downstream of Keighley. This storage area is considered in ongoing work for phase 2 of the Leeds FAS. The benefits to Keighley and other areas on the River Aire between the storage area and Leeds should be considered in the assessment of this storage area.

Table 1.2 Options taken forward for assessment

Option	Source of Flooding Addressed	Standard of Protection	Description
Option 1	River Aire	1in100 years + Climate Change	<ul style="list-style-type: none"> Raise Stockbridge FAS
Option 2	River Aire	1in200 years + Climate Change	<ul style="list-style-type: none"> Raise Stockbridge FAS
Option 3a	River Worth	1in100 years + Climate Change	<ul style="list-style-type: none"> Reinstate and raise River Worth FAS Remove 'Ski Jump' weir
Option 3b*	River Worth	1in50 years	<ul style="list-style-type: none"> Reinstate River Worth FAS
Option 3c*	River Worth	1in50 years	<ul style="list-style-type: none"> Reinstate River Worth FAS and Improve Informal 3rd Party Defences (460m)
Option 4	River Worth	1in200 years + Climate Change	<ul style="list-style-type: none"> Reinstate and raise River Worth FAS Remove 'Ski Jump' weir Implement upstream flood storage area on River Worth at Grey Scar Lane and Damens Road
Option 5	All sources	1in100 years + Climate Change	<ul style="list-style-type: none"> Raise Stockbridge FAS Reinstate and raise River Worth FAS Remove 'Ski Jump' weir Install permanent pumps at Florist Street
Option 6	All sources	1in200 years + Climate Change	<ul style="list-style-type: none"> Raise Stockbridge FAS Reinstate and raise River Worth FAS Remove 'Ski Jump' weir Implement upstream flood storage area on River Worth at Grey Scar Lane and Damens Road Install permanent pumps at Florist Street

**Options added following further discussion with key stakeholders after this report had been issued; the data presented is for information only and may not be directly referred to within the report*

Within Options 1 and 2 no reinstatement of the River Worth Scheme takes place and these defences continue to deteriorate and fail as in the Do Minimum scenario.

In addition to reinstating the Worth scheme to a 1in50year SOP, further investigation was undertaken into providing a higher standard of protection along this section of the Worth – i.e. defences are raised to provide a 1in100year plus climate change standard - however, there may be significant costs associated with carrying this out due to the technical challenges of raising the

scheme to this level. In order to provide a standard greater than this flood storage areas upstream of Keighley are used. A combination of upstream storage and reinstatement of the River Worth scheme could also be used to achieve the 1in100 (1% AEP) plus climate change SOP.

In Options 5 and 6 there would be expected to be a cost saving in the design and construction of the defence schemes due to efficiency savings from work on both schemes at the same time. The benefits of this have not been estimated in this assessment and the costs of Options 5 and 6 are equal to the costs of the separate components.

1.4.3 Costs of options

The costs for the options were calculated using the Environment Agency's Project Cost Tool and Long Term Costing Workbook. The maintenance and operation costs relate to mechanical maintenance of the assets to Target Condition 3. Costs for land purchase associated with the River Worth storage areas were provided by Bradford MDC.

It is assumed that a major replacement of assets will be required at some point during the appraisal period after the initial construction phase. The timing of these replacements is based on the EA's Asset Deterioration Guidance (2013), and the assumptions are outlined in Appendix B.

An appraisal period of 100 years has been used. A detailed breakdown of costs across this period is included in Appendix B.

Table 1.3 shows the build-up of costs for all options.

Table 1.3 Project initial costs and annual maintenance (£k)

Item	Option 1	Option 2	Option 3a	Option 3b*	Option 3c*	Option 4	Option 5	Option 6
Construction Costs	4,227	4,453	4,908	4,006	5,705	6,418	9,473	11,208
Environment Agency staff	300	316	348	296	422	580	702	949
Consultant fees (appraisal)	207	218	240	208	297	325	469	565
Consultant fees (design)	571	601	663	569	810	954	1,306	1,628
Consultant fees (construction)	241	254	280	236	337	355	540	628
Site investigation & survey	161	169	186	160	228	209	352	383
Land Purchase	21	22	25	20	29	32	47	558
Optimism bias (44%)	2,520	2,655	2,926	2,418	3,444	4,125	5,671	7,005
TOTAL	8,249	8,689	9,576	7,916*	11,271*	13,500	18,561	22,926
Annual Operation and Maintenance Costs (£, including optimism bias)	5,119	5,119	5,119	1,800	1,900	6,776	14,834	16,491

**Options added following further discussion with key stakeholders after this report had been issued; the data presented is for information only and may not be directly referred to within the report*

1.5 Initial environmental assessment

The study area is heavily urbanised and within this area the River Worth is a highly modified channel. As such the proposed works are not expected to significantly worsen the environmental impact of the existing defences. Options providing higher levels of protection would have greater negative impacts due to the more significant construction work taking place. The main impacts of each of the proposed areas of work are summarised in Table 1.4:

Table 1.4 Key environmental impacts, mitigation and opportunities

Key positive impacts	Key negative impacts	Mitigation/ enhancement opportunity
Reinstate River Worth FAS		
Reduced risk of flooding	Construction work takes place alongside watercourse. Risk of pollution incidents and disruption to area during construction Visual Impact on area from increased wall height	Best practice should be followed including referring to EA Pollution Prevention Guidance
Removal of Ski Jump Weir		
Removal of current weir will have ecological benefits by removing restriction to fish movement	Work takes place within watercourse. Risk of pollution incidents and disruption to area during construction	Best practice should be followed including referring to EA Pollution Prevention Guidance
Reinstate Stockbridge FAS		
Reduced risk of flooding	Construction work takes place alongside watercourse. Risk of pollution incidents and disruption to area during construction Visual Impact on area from increased wall height	Best practice should be followed including referring to EA Pollution Prevention Guidance
Installation of Permanent Pumps at Florist Street		
Reduced risk of surface water flooding	Ongoing operational requirements of pumping station including energy use	
Upstream flow Attenuation of River Worth		
Reduced risk of flooding Reduced risk of failure of 3 rd party assets Increased wetland, increase in wild species diversity potential recreational benefits	Loss of agricultural land due to storage area	Early engagement with landowners recommended to enhance opportunities and minimum negative impacts
Upstream flow Attenuation of River Aire		
Reduced risk of flooding Increased wetland, increase in wild species diversity potential recreational benefits	Loss of agricultural land due to storage area	Early engagement with landowners recommended to enhance opportunities and minimum negative impacts

1.6 Consultation

The options in this appraisal were developed in consultation with the Environment Agency and Bradford MDC. No public consultations were held at this stage as the work is a high-level assessment of potential options. Stakeholder engagement will take place at subsequent stages of the project.

If this project is taken forward for further appraisal it is recommended that consultation is focused on, but not limited to, the following:

- Residents in the area at risk
- Landowners and developers for the upstream storage options. Especially Airedale IDB as owner of the land proposed for storage at Holden Park.

Riparian landowners, especially owners of riverside walls acting as informal defences.

1.7 Economic summary and preliminary preferred option

In order to quantify the benefits of a scheme the modelled flood outlines from the 2007 Worth study and 2008 Aire study were used to estimate the properties currently located within the risk band set by DEFRA outcome measures. The 1 in 25 year outline is assumed to represent properties at risk from a 1 in 20 year incident, the Very Significant risk band, as no outline is available for this.

Properties within the 1 in 25 year outline were assessed as being in the Very Significant risk band, Properties within the 1 in 75 year outline were assessed as being in the Significant Risk band and properties within the 1 in 200 year outline were assessed as being in the Moderate Risk band.

The Areas benefiting from defences outlines have been used to assess the properties that benefit from the two defence schemes. The options considered increase the standard of protection provided by the schemes and therefore properties that currently benefit from the defences are the properties that benefit from the options. Only properties that benefit from at least one of the defence schemes are considered. There are additional properties at risk within Worth Village but these are not assessed to benefit from any of the Options considered.

In their current condition the River Worth defences are assumed to be at risk of breaching. In Options that do not reinstate these defences there is a risk of flooding due to failure of defence assets.

Table 1.5 Number of Properties at Risk (based on current outlines and SOP of existing schemes)

Property Type	Flood Risk	Number of Properties
Residential	≥1 in 20 year (5% AEP) (Very Significant Risk)	0
	<1 in 20 year (5% AEP) ≥1 in 75 year (1.33% AEP) (Significant Risk)	369
	<1 in 75 year (1.33% AEP) ≥1 in 200 year (0.5% AEP) (Moderate Risk)	19
Non-Residential	≥1 in 20 year (5% AEP) (Very Significant Risk)	0
	<1 in 20 year (5% AEP) ≥1 in 75 year (1.33% AEP) (Significant Risk)	11
	<1 in 75 year (1.33% AEP) ≥1 in 200 year (0.5% AEP)	39

Detail of the methodology used for assessing the benefits of each option is detailed in Appendix C.

An appraisal period of 100 years is assumed based on FCERM appraisal guidance and the expected lifespan of new assets. Two standards of protections are considered; 1 in 100 (1%) AEP with climate change and 1 in 200 (0.5%) AEP with climate change. This ensures that the options considered will provide a good level of protection throughout the appraisal period.

Table 1.6 summarises the economic assessment carried out for all options. The calculations for PV benefits are shown in Appendix D. The options are ordered by the assumed benefits (lowest benefit first).

These benefit values are estimates based on the methodology detailed in Appendix C. There is significant uncertainty in these estimates and if further appraisal is carried out the benefits of these options should be more accurately assessed though hydraulic modelling and use of depth-damage calculations.

Table 1.6 Benefit-cost assessment

	PV costs (£k)	PV benefits (£k)	Av. BCR	Incr' BCR	Option for iBCR calc	Comments
Do Nothing						
Do Minimum	153	2,526	16.51			
Option 1 – Stockbridge FAS 1in100 + CC	8,556	2,526	0.30			No benefit due to failure of River Worth FAS
Option 2 - Stockbridge FAS 1in200 + CC	9,004	3,021	0.34			Low benefit due to failure of River Worth FAS
Option 3a – River Worth FAS 1in100 + CC	9,908	13,609	1.37	1.06	Do Minimum	Preferred option due to ABCR and IBCR
Option 3b* – River Worth FAS 1 in 50 + CC	8,340	12,030	1.44	1.16		*
Option 3c* – River Worth FAS 1in 50 + CC & 3rd Party Assets	11,855	16,810	1.42	0.85		*
Option 4 - River Worth FAS 1in200 + CC	13,955	15,058	1.08	0.32	Option 3a	
Option 5 – All sources of flooding 1in100 + CC	19,397	14,298	0.74			
Option 6 – All sources of flooding 1in200 + CC	23,886	15,990	0.67			

**Options added following further discussion with key stakeholders after this report had been issued and is to aid in the next scheme appraisal stage; hence it may not be directly commented upon the report and should be used as indicative guidance only. .*

The Do Minimum scenario has the highest ABCR justifying the continuation of the current maintenance regime. This option has no capital costs and high benefits in the early years of the appraisal period from the current River Worth defences. This may be viable in the short term if ongoing maintenance can manage the risk of the scheme failing. However with no capital investment the River Worth FAS will continue to deteriorate and eventually fail.

Options 1 and 2 have low benefits as the River Worth FAS is assumed to fail. Without protection from the River Worth the majority of properties that would benefit from the Stockbridge FAS are at high risk of flooding. There are no properties at risk in the Do Minimum scenario that are not at risk in Option 1. As such this option has no increase in benefits. Whilst the same properties are affected this option would reduce flooding depths and increase warning time leading to reduced damages. This is not taken into account in the WAAD methodology used.

Options 5 and 6 have relatively low increases in benefits compared to Options 3 and 4. The existing Stockbridge scheme is assumed to be in reasonable condition and to provide a 1in75 (1.33%) SOP throughout the appraisal period. As such the benefits of raising this are significantly less than those from work on the River Worth.

Construction of storage areas on the River Aire or River Worth would provide these benefits and would also have significant benefits beyond the study area. Storage on the Aire would benefit the areas at risk downstream of Keighley including Bingley, Baildon and Leeds. Storage on the Worth would benefit other areas in the Worth catchment including Haworth and the area at risk of flooding from North Beck. Use of storage areas would have greater benefits than providing the same SOP to Worth Village by raising defences.

The Partnership Funding score for the options considered has been calculated as shown in Table 1.7. The benefits period for these options is based on the lifespan of the assets. This period is 90 years for all options as this is the expected time for a flood wall to deteriorate to the point of failure. Beyond this further investment will be needed to reinstate or replace the assets. The details of this calculation and sensitivity testing are including in Appendix E.

Table 1.7 Outcome measures and Partnership Funding Score

Contributions to outcome measures	Option 1 – Stockbridge FAS 1in100 +CC	Option 2 – Stockbridge FAS 1in200 +CC	Option 3a – River Worth FAS 1in100 +CC
OM1 – Economic Benefit:			
<i>Benefit period used for Partnership Funding calcs</i>	90	90	90
<i>PV Benefits</i>	£2,525,967	£3,012,377	£13,342,587
<i>PV Costs</i>	£8,398,623	£8,838,623	£9,725,623
<i>Benefit/Cost ratio</i>	0.30	0.34	1.37
OM2 – No. of households moved out of any flood probability category to a lower category	0	7	337
OM2b – No. of households for which the probability of flooding or coastal erosion is reduced from the very significant or significant category to the moderate or low category	0	0	325
OM2c – No. of households in the 20% most deprived areas moved from the very significant or significant flood probability category to the moderate or low category	0	0	13
OM4a – Hectares of water dependent habitat created or improved to help meet the objectives of the Water Framework Directive	0	0	0
OM4b – Hectares of intertidal habitat created to help meet the objectives of the Water Framework Directive for areas protected under the EU Habitats/Birds Directive	0	0	0
OM4c – Kilometres of rivers protected under the EU Habitats/Birds Directive improved to help meet the objectives of the Water Framework Directive	0	0	0
Partnership Funding (PF) Score	2%	2%	17%
Contributions required for a PF score of 100%	£8,258,292	£8,663,750	£8,111,772

Contributions to outcome measures	Option 1 – Stockbridge FAS 1in100 +CC	Option 2 – Stockbridge FAS 1in200 +CC	Option 3a – River Worth FAS 1in100 +CC
Contributions required for a PF score of 120%	£8,281,200	£8,692,300	£8,375,200

Contributions to outcome measures	Option 4 – River Worth FAS 1in200 +CC	Option 5 – All Sources of Flooding 1in100 +CC	Option 6 – All Sources of Flooding 1in200 +CC
OM1 – Economic Benefit:			
<i>Benefit period used for Partnership Funding calcs</i>	90	90	90
<i>PV Benefits</i>	£14,763,121	£14,017,600	£15,676,336
<i>PV Costs</i>	£13,698,055	£18,994,582	£23,408,015
<i>Benefit/Cost ratio</i>	1.08	0.74	0.67
OM2 – No. of households moved out of any flood probability category to a lower category	337	369	388
OM2b – No. of households for which the probability of flooding or coastal erosion is reduced from the very significant or significant category to the moderate or low category	325	369	369
OM2c – No. of households in the 20% most deprived areas moved from the very significant or significant flood probability category to the moderate or low category	13	13	13
OM4a – Hectares of water dependent habitat created or improved to help meet the objectives of the Water Framework Directive	0	0	0
OM4b – Hectares of intertidal habitat created to help meet the objectives of the Water Framework Directive for areas protected under the EU Habitats/Birds Directive	0	0	0
OM4c – Kilometres of rivers protected under the EU Habitats/Birds Directive improved to help meet the objectives of the Water Framework Directive	0	0	0
Partnership Funding (PF) Score	15%	9%	10%
Contributions required for a PF score of 100%	£11,694,720	£17,193,929	£21,157,383
Contributions required for a PF score of 120%	£12,021,700	£17,487,800	£21,524,700

*Options 3b and 3c were separated assessed following the production of this report and looked to obtain partnership funding scores of:

- 18% (3b) – estimate of external contributions required for a PF score of 100% £6,706,557
- 18% (3c) – estimate of external contributions required for a PF score of 100% £9,333,660

The information provided above is show to aid in further appraisal of the schemes and should be considered for guidance purposes only.

1.7.1 Limitations and Uncertainties

This initial assessment has produced a high-level appraisal of options available to manage flood risk in Worth Village. There are limitations to the methodology applied and more robust appraisal would be required to have greater confidence in the results.

Costs for options are based on the EA Long term costing tool. This uses average costs from similar construction projects. Work within the Worth Village area is likely to be constrained by the urban area and may have a high cost. There is considerable uncertainty within this cost assessment. The construction costs may change significantly with a greater understanding of the technical challenges and opportunities involved.

The Weighted Annual Average Damages (WAAD) from the Multi-coloured Manual have been used to assess damages and hence benefits. This assesses damages based on the number of properties affected. This does not take into account the depths of flooding and more accurate damages could be calculated if information on expected flood depths was available.

The WAAD methodology is unsuitable for assessing the impacts of climate change. Defences have been assessed as provided a constant standard of protection throughout the appraisal period. Options accounting for climate change will provide a higher standard of protection early in the appraisal period.

The level of protection provided by the storage areas is uncertain. The two areas assessed have been used as land purchase costs for these were available. The volume of storage available in these areas has not been assessed and would need to be modelled to establish how much storage is available and how much benefit this will provide for Worth Village.

1.7.2 Funding and contributions

A funding analysis tool was used to identify potential direct and indirect beneficiaries of the scheme. This is included in Appendix E. Based on these beneficiaries potential funding sources identified include:

- Community Infrastructure Levy
- Benefitting local businesses
- Council Tax
- Local Enterprise Partnerships

There are a large number of commercial properties at risk within the town. Further consultation would be required to identify potential contributions.

1.7.3 Key delivery risks (economic, social and environmental)

Key delivery risk and recommendations for mitigating these risks are shown in the table below.

Table 1.8 Risks and mitigation

Risk	Key Mitigation
Technical challenges with access to River Worth FAS leading to high cost associated with raising defences	Consider the use of upstream storage areas in further appraisal to minimise the raising of the River Worth FAS
Stockbridge FAS may provide a lower SOP than design standard or be at risk of failure	Review the performance of this scheme using data from Boxing Day event and determine the current SOP provided
Land for proposed storage areas not available or has high associated cost	Screening of all potential storage areas should be undertaken to eliminate inappropriate areas
Costs of flood storage area construction and operation greater than estimated cost	More detailed assessment of the potential storage areas should be undertaken using hydraulic modelling to assess the level of construction required, the volume of storage available and the frequency that the storage area will need to be operated
Insufficient 3 rd party Funding available to allow scheme to progress	Assess potential funding options before progressing scheme appraisal further.

1.8 Project Scoring

The data used in this assessment has been subjected to a RAG assessment. This gives a three figure score with the first number being the number of reds, where there is significant uncertainty or challenges. The second and third numbers are the numbers of amber and greens. The results are shown below:

- A – Problem Definition: The fluvial flooding is well defined with flood outlines but further investigations required to understand the surface water flooding mechanisms – **AMBER**
- B – Economic: There are limitations to the methodology applied and more robust appraisal would be required to have greater confidence– **RED**:
- C – Funding: The options are likely to require external funding. Alternative funding sources have been identified – **AMBER**
- D – Engineering case: Solutions taken to outline design are tried and tested defence options – **AMBER**
- E – Permissions & Consents: Solutions are likely to require usual permissions or consents but not considered to be a major constraint– **AMBER**
- F – Environmental sensitivities: Initial environmental assessments has been completed based on outline options, some impact with wall options, storage option could create opportunities – **AMBER**
- G – Opportunities: Some potential opportunities for partnership working and environmental opportunities from storage options – **AMBER**

Model.	Econ.	Funding	Eng.	Permission	Env.	RAG	Opps.
A	B	C	D	E	F		G
2	3	2	2	2	2	150	2

1.9 Further work requirements

If the project is taken forward for further appraisal it is recommended that the following work is carried out to improve confidence in this assessment:

- Assessment of performance of Stockbridge scheme following Boxing Day event to confirm the standard of protection provided by these defences.
- Detailed screening of all potential FSAs in the River Worth catchment identified in Upper Aire modelling study to assess expected compensation costs and technical feasibility of these areas.
- Appraisal of FSAs in the River Worth catchment to assess benefits of these for the entire Worth catchment and the River Aire downstream of Keighley. Assess costs of construction and operation of these areas in detail to update economic assessment.
- Following the above modelling, undertake a preliminary funding study to consider beneficiaries in the Worth and Upper Aire catchments and the potential for 3rd party funding in the overall benefit area to meet the funding gap.
- Inclusion of benefits to Worth Village and other areas along the River Aire upstream of Leeds in the appraisal of storage areas on the River Aire as part of the Leeds FAS.
- Further consultation with YWS to investigate potential to reduce flood risk through operation of sewer network.

1.10 Conclusions and Recommendation

This assessment has considered measures to reduce flood risk from various sources within the Worth Village area of Keighley. There was significant flooding in the area during Boxing Day 2015 from the River Worth and from surface water flooding.

Properties within Worth Village are at risk of flooding from the River Worth and River Aire overtopping the flood defences. There is also a risk of surface water flooding where the drainage network cannot discharge during high river levels. Due to the poor condition of the River Worth FAS there is currently a risk of flooding due to the assets within this scheme failing.

A range of options have been considered to reduce the risks of flooding. The options assessed raise the Standard of Protection (SoP) provided by the Stockbridge FAS and River Worth FAS as well as addressing surface water flooding.

The economic analysis shows that the Do Minimum scenario is beneficial and that the current maintenance regime should be continued. The River Worth FAS is expected to breach in this scenario leading to high flood damages. There are however significant economic benefits from the scheme in its current condition even with a high risk of breaching.

It is recommended to reinstate the River Worth FAS as there is the potential for a large number of properties to be affected by a breach. Whilst the BCR suggests it may be advantageous to delay this replacement, there will be benefits with reducing flood risk beyond those assessed in the economic analysis. The recent breach of the Stockbridge Scheme in the 2000 flooding could worsen the reputational impact of a breach in the scheme.

The preferred Do Something option is to raise the SOP provided by the River Worth FAS to 1in100 (1%) AEP plus climate change. This has high benefits and the assessment has considered achieving this standard of protection by raising the level of defences.

Following this assessment this option has a Partnership Funding score of 17% and would require significant funding contributions to proceed.

A 1in100 (1%) AEP standard of protection for the River Worth could be provided through a combination of raising defences and upstream storage. There is expected to be technical

challenges with raising defences in this location and upstream storage may provide a more economical solution.

Upstream storage on the River Worth will provide benefits for other areas in the Worth catchment that were flooded on Boxing Day 2015 and remain at risk of flooding including Haworth. This will also reduce flood risk to areas in Keighley not protected by formal flood defences. This will have greater benefits than estimated in this assessment as only properties benefiting from the River Worth FAS were considered.

It is not seen to be economically viable to raise the level of the Stockbridge defences. The existing defences provide a 1in100 (1%) AEP standard of protection and it is thought that this standard can be sustained with current maintenance work.

The risk of flooding from the River Aire can be reduced through the use of storage areas upstream of Keighley. This would have significant benefits for other areas along the Aire that were flooded on Boxing Day 2015 including Bingley, Baildon and Leeds. The benefits to Keighley should be considered in any appraisal of storage areas on the Aire.

1.10.1 Recommendations

- The potential storage areas identified on the River Aire in the Upper Aire SFRA should be assessed further. This assessment should include the benefits to Worth Village and to other sites along the River Aire.
- Improving the standard of protection provided by the River Worth FAS should be taken forward for further appraisal. This should consider combinations of reinstatement of defences and upstream storage to provide the level of protection required.
 - This should consider the benefits to the entire Worth catchment especially Haworth and North Beck where there is a known risk of flooding.
 - The potential storage areas should be assessed to investigate technical feasibility, environmental constraints and the costs associated with using these.
 - Hydraulic modelling should be carried out for any viable storage areas to assess the benefits of each area and increase in standard of protection provided.
- Measures to address surface water flooding in Worth Village should also be investigated in more detail.
 - The area and number of properties at risk of surface water flooding should be identified
 - Efforts to alleviate surface water through operation of the sewerage network should be investigated in detail with YWS

Appendices