River Hull Advisory Board

River Hull Integrated Catchment Strategy

May 2016

Strategy Document

"Providing long term sustainable management of flood risk"
This document was issued and approved as follows:

**Version Control**

<table>
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<th>Originator</th>
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**Partner Approvals Record**

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Approver</th>
<th>Date of Approval</th>
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</thead>
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<tr>
<td>East Riding of Yorkshire Council</td>
<td>Cabinet</td>
<td>7 July 2015</td>
</tr>
<tr>
<td>Hull City Council</td>
<td>Cabinet</td>
<td>22 June 2015</td>
</tr>
<tr>
<td>Environment Agency</td>
<td>Area Flood and Coastal Risk Manager</td>
<td>3 July 2015</td>
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<tr>
<td>Beverley &amp; North Holderness Internal Drainage Board</td>
<td>Board</td>
<td>8 July 2015</td>
</tr>
<tr>
<td>Yorkshire Water</td>
<td>Flood Risk Manager</td>
<td>9 July 2015</td>
</tr>
<tr>
<td>River Hull Advisory Board</td>
<td>Board</td>
<td>10 July 2015</td>
</tr>
</tbody>
</table>

Through the above approval the partners are recognising the work that has been carried out to produce the River Hull Integrated Catchment Strategy which sets out a holistic and strategic approach to managing the flood risk for the River Hull catchment.

The partners have agreed to have regard to this Strategy in formulating their future proposals for managing flood risk within the catchment. The progression of individual projects or interventions identified within this Strategy will be subject to the normal assurance and approval processes of the individual body concerned and those of any relevant funding body.
Contact information

For further information about this Strategy, please contact us using the details below.

Email: floods@eastriding.gov.uk

Web: www.eastriding.gov.uk/flooding

Post: Flood Risk Strategy, County Hall, Cross Street, Beverley, HU17 9BA
It is important for the reader to fully understand that this document is produced for consideration by the approval bodies of multiple organisations with differing constitutional and accountability arrangements, these are:

- The Cabinet of Elected Members: East Riding and Kingston upon Hull City Councils
- EA (Delegated to Area Flood and Coastal Risk Manager)
- The Beverley and North Holderness Internal Drainage Board
- Board of Directors: Yorkshire Water (Delegated to Senior Officer)

; and in respect of environmental assessments:

- Natural England: (Delegated to Senior Officer, NE York)

All 5 flood risk management authorities and the Local Enterprise Partnership (LEP) are funding authorities. Capital funding for this project will be directed in the following ways:

- Humber LEP: Multiple sources of funding through a local assurance system and commitments in the Humber growth Deal
- Yorkshire Water: Regulated funding within parameters agreed by Ofwat (the Water Services Regulation Authority)
- EA: Flood Defence Grant-in Aid only within a national assurance framework on behalf of Defra.

Detailed information about governance arrangements for capital funding can be found at 12.4.

Whilst an exhaustive effort has been made to address the requirements of all the approving bodies, should clarification or further supplementary information be required the reader should contact a member of the RHICS project team in advance of approval deadlines.
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SECTION 1: EXECUTIVE SUMMARY

The River Hull Integrated Catchment Strategy (RHICS) aims to provide a long term, sustainable multi-agency plan to manage flood risk from multiple sources within the natural River Hull catchment.

1.1 **Background**

1.1.1 RHICS has been prepared by the River Hull Advisory Board (RHAB) on behalf of the five Flood Risk Management Authorities that have varied but complementary functions within the catchment. The Board (RHAB) was established specifically to develop the River Hull Integrated Catchment Strategy to provide for a comprehensive assessment of all sources of inland flooding (fluvial, pluvial, surface water, and groundwater). The study provides an integrated framework for the management of flood risk in the natural River Hull Valley, (“the study area”) for the Flood Risk Management Authorities (RMAs):

a) Beverley and North Holderness Internal Drainage Board (BNHIDB).
b) East Riding of Yorkshire Council (ERYC).
c) Environment Agency (EA).
d) Kingston upon Hull City Council (HCC).
e) Yorkshire Water Services Ltd (YW).

1.1.2 The study area is one of the most ‘at-risk’ developed flood plains in England, with a land area of approximately 980 km² and a population of approximately 386,000. Without defences, an area of approximately 5,500 ha of land and nearly 131,000 residential properties would be subject to flooding from the sea, river, surface water and groundwater.

1.2 **Project innovation**

1.2.1 The strategy contains several innovative approaches that make it unique:

- It has been produced jointly by all the (five) Risk Management Authorities in the area working together
- It has been led by a local authority as project executive; the project executive has also procured and managed consultancy services and has acted as lead strategy author
- A multi-agency independently-chaired advisory body was set up to oversee strategy development. Other than the five RMAs, it includes representatives from other statutory bodies, local communities, river users, land owners and business interests
- It is integrated, in that it considers flood risk from all known sources: tidal influences, fluvial (rivers), pluvial (rainfall), surface water (flooding from sewers and overland flows), and groundwater (springs) and how they interact with each other

---

1 2011 Census
• This has required one of the most sophisticated and powerful computer programmes to be developed (modifying an industry standard and quality-assured modelling programme) to model flooding and how possible solutions might reduce risk
• It has been supported by the Humber Local Enterprise Partnership, which has also committed to contribute funding to projects which will reduce business risks and help open constrained land to development opportunities, and whose Strategic Economic Plan recognises the importance of managing flood risk to the sub-region’s economy
• Some project delivery and procurement will be led by partners not traditionally responsible for particular functions, such as local authorities or the internal drainage board taking on main river assets.

1.3 Modelling and economics

1.3.1 The principal information source for the study has been an enhanced industry-standard integrated computer hydraulic model - InfoWorks® Integrated Catchment Model (ICM) v4). The model predicts flood risk from all sources affected by fluvial, pluvial and groundwater derived flows, in combination with backwater influences from modelled tidal events at confluences with the Humber Estuary. Data taken from specially commissioned 2014 surveys of the River Hull, main watercourses, drains and embankment levels was added into the computer model and, by using agreed antecedent conditions from a November 2012 storm event, flood extents and baselines established. Over 70,000 Yorkshire Water sewer network data points were also added. Section 6 deals with model construction, including details of the 2014 bathymetric survey (with further information in Appendix A).

1.3.2 In accordance with the Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG) and the Multi-coloured Manual (MCM2013) the study identified damages to residential and commercial properties, agricultural land, vehicles, and temporary accommodation and health buildings. From baseline data sets alternative flood mitigation measures were then developed into a range of options for assessment. Section 7 deals specifically with economic appraisal.

1.3.3 To ensure that potential flood management schemes around the Humber do not double count potential benefits, partners are working with a consultant on a new agreement that will seek to apportion benefits fairly. Section 6 deals with the current state of progress.

1.4 Option development

1.4.1 The study generated 18 catchment options for consideration, with 16 taken forward for further modelling, engineering, environmental and economic assessment. These consisted of:

a) Four options varying the capacity of pumping stations at East Hull, Great Culvert, Waterside, Bransholme, Tickton, Wilfholme and Hempholme.

b) Two options to re-profile channels on the River Hull and Holderness Drain.

c) Options to manage offline storage for the River Hull and Holderness Drain at three potential locations combined with changes to pumping.
d) Two options to raise embankments at the Holderness drain east of Bransholme and the Beverley & Barmston Drain west of Dunswell.

e) Options for natural upland attenuation.

f) Two sluice options for tidal exclusion, both with and without additional offline storage.

1.4.2 Through an iterative process the final strategy proposes a single multifaceted solution

Table 1 - Summary of recommendations for the River Hull catchment.

<table>
<thead>
<tr>
<th>Option label</th>
<th>Description</th>
<th>CAPEX +60% OB</th>
<th>OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dredging and Re-profiling the river Hull Channel. Including the removal of sunken boats</td>
<td>£751,456</td>
<td>£30,000</td>
</tr>
<tr>
<td>B</td>
<td>Sluicing for Tidal Exclusion using Tidal barrier at River Hull Mouth</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mitre gates*</td>
<td>£13,802,400*</td>
<td>£75,000*</td>
</tr>
<tr>
<td>C</td>
<td>Increased capacity at pumping stations and raising of embankments along Holderness Drain</td>
<td>£8,448,000</td>
<td>£173,000</td>
</tr>
<tr>
<td>D</td>
<td>Bransholme flood mitigation</td>
<td>£16,000,000</td>
<td>-</td>
</tr>
<tr>
<td>E</td>
<td>Raising of embankments along the Beverley and Barmston Drain</td>
<td>£5,184,000</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>New pumps installed at Wilfholme and Hempholme pumping stations</td>
<td>£1,200,000</td>
<td>£50,000</td>
</tr>
<tr>
<td>G</td>
<td>Upland Natural Attenuation – 25% upland assigned.</td>
<td>£372,960</td>
<td>£62,500</td>
</tr>
<tr>
<td>H</td>
<td>Maintenance of existing assets</td>
<td>£1,230,291</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>£45,758,816</td>
<td>£1,620,791</td>
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</table>

* Mitre gates solution now deemed unnecessary for early implementation. Tidal barrier to be used until asset expired. Mitre gates would be preferred solution thereafter.

that consists of eight components. It is essential to stress that these are components of a single solution, rather than elective options. The components are set out below in Table 1.
1.5 Other flood risk management actions

1.5.1 The five RMAs have a large programme of potential works to manage flood risk within the catchment – almost 80 schemes have been identified for future funding, with some of this already approved. The nature of the schemes reflects the differing responsibilities of the RMAs.

1.5.2 The River Hull catchment has three sub-catchments (see Figure 5 below). Flood Risk Management Plans are being prepared for each, and two are already subject to consultation on draft plans (the River Hull FRMP for the middle and upper Hull, and the Hull & Haltemprice FRMP, largely covering the west Hull suburbs and villages). These will set the context for future flood risk management schemes.

1.5.3 Details of RMA’s proposed capital schemes throughout the catchment are available online or by contacting relevant teams, Table 2 below gives a broad indication of the type of works or plans in these programmes.

1.5.4 The Environment Agency’s own capital programme contains large scale projects to defences (embankments and wharves) on the River Hull in its lower, middle and upper reaches, including to some of the larger lateral feeder drains. Pumping station upgrades also feature, but some of these now form part of RHICS’ considerations. There is also a scheme (underway) that deals with tidal flooding from the Humber.

1.5.5 The East Riding of Yorkshire Council schemes are largely local flood alleviation schemes in villages or to the highway network, dealing with different causes of surface water flooding. It is also acting as the lead for joint schemes with the City Council for large scale flood alleviation schemes (storage lagoons) in the Wolds valleys in the western suburbs.

1.5.6 The City Council’s schemes are also surface water schemes, dealing with local ‘hot spots’ of localised more frequent flooding, in co-operation with Yorkshire Water Services.

1.5.7 Yorkshire Water’s main flood risk management investment over recent years has been to upgrade the capacity of its sewer network pumping stations. Its Bransholme PS upgrade forms part of RHICS, as does its East Hull PS, as part of the Holderness Drain component. Funding is to be provided to further develop an urban drainage study of the Hull & Haltemprice area.

1.5.8 Beverley & North Holderness Internal Drainage Board’s programme focusses on improving the conveyance on watercourses, either by re-grading sections of them or improving structures within or over them.
A detailed description and appraisal of each option can be found in Section 9. Subject to financial, technical and regulatory approval, these options are to be delivered phased over 20 years. Strategy components are outlined in more detail in Section 11. Figure 1 below shows the location of the proposed options.

### Table 2 - Other flood risk management schemes, by RMA and type

<table>
<thead>
<tr>
<th>RMA</th>
<th>Scheme type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment Agency</td>
<td>• Large schemes for defences improvements to the River Hull and feeder drains</td>
</tr>
<tr>
<td></td>
<td>• Pumping station refurbishment</td>
</tr>
<tr>
<td></td>
<td>• Floodgate and outfall works</td>
</tr>
<tr>
<td></td>
<td>• Habitat enhancements</td>
</tr>
<tr>
<td></td>
<td>• Humber defences</td>
</tr>
<tr>
<td>East Riding of Yorkshire Council</td>
<td>• Village flood alleviations schemes</td>
</tr>
<tr>
<td></td>
<td>• Ordinary watercourse improvements</td>
</tr>
<tr>
<td></td>
<td>• Highway culvert and gulley improvements</td>
</tr>
<tr>
<td></td>
<td>• FRMP preparation</td>
</tr>
<tr>
<td>Hull City Council</td>
<td>• Local flood alleviation schemes</td>
</tr>
<tr>
<td>Joint schemes</td>
<td>• West Hull villages flood alleviation schemes</td>
</tr>
<tr>
<td>B&amp;NHIDB</td>
<td>• Watercourse conveyance improvements</td>
</tr>
<tr>
<td></td>
<td>• Bridge and culvert improvements</td>
</tr>
<tr>
<td></td>
<td>• Local flood alleviation schemes</td>
</tr>
<tr>
<td></td>
<td>• Pumping station improvements</td>
</tr>
<tr>
<td>Yorkshire Water</td>
<td>• Bransholme pumping station upgrade</td>
</tr>
<tr>
<td></td>
<td>• Hull &amp; Haltemprice area drainage network study</td>
</tr>
</tbody>
</table>
Figure 1 - Component location map
1.6 Environmental assessment

1.6.1 A Strategic Environmental Assessment has been prepared to accompany the strategy. It is an update and based upon the EA’s 2010 SEA prepared for the (unadopted) River Hull Flood Risk Management Strategy. It has assessed the eight components in depth, but options which failed the initial sifting (such as the major drain diversions) and other options subsequently rejected on cost grounds (largely off-line storage lagoons) were subject to a less detailed assessment. An allowance was made to undertake a Habitat Regulations Assessment should the SEA identify potential harm to the Humber’s wildlife designations. An HRA was subsequently undertaken. The recommendations from the SEA and HRA have been incorporated into each of the project options in Section 9. Section 10 brings these together as recommendations for further assessment or opportunities for environmental enhancement.

1.7 Consultation

1.7.1 A non-technical summary (a ‘Preferred Approach’ draft) of the strategy was issued for consultation in November 2014 following approval by the five RMA’s boards/cabinets. Travelling roadshows aboard a mobile exhibition vehicle were arranged for Driffield, Beverley and Hull, and an event held at County Hall Beverley for an invited audience. The strategy has its own web page on the ERYC website. 120 consultees were invited to make representations on the preferred approach; 77 comments were received. A consultation report has been prepared for the web site.

1.7.2 A draft SEA and draft full strategy were published for consultation for six weeks in April and May 2015. The draft HRA was issued for consultation for three weeks in May 2015. Consultation was targeted at those who responded to the Preferred Approach draft, and the documents placed on the website.

1.7.3 Separate documents published alongside the strategy include a summary of comments received, and responses, against the components and recommendations of RHICS.

1.8 Implementation

1.8.1 Table 3 shows a summary of how solutions will be implemented. The phasing shown may change as a result of additional economic assessment, but it is intended that all phases should commence within six years (i.e. by 2020). A project lead is identified for each of the components; these will have the responsibility for co-ordinating relevant partners, bidding for and securing the funding, carrying out any additions environmental assessments, and obtaining any other consents.

1.9 Further actions

1.9.1 The Strategy also makes recommendations on:

- Data retention and management
- The future role and function of the Advisory Board and its sub-boards
- The creation of a new single navigation authority for the whole of the River Hull
- Potential for connecting the River Hull with social and business type functions.

Potential legal issues are addressed. These can be found in Section 11.
<table>
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<th>Component</th>
<th>Project Executive</th>
<th>When</th>
<th>Funding</th>
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<tr>
<td><strong>A</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dredging</td>
<td>ERYC</td>
<td>2016 - 2017</td>
<td>FDGiA/LGF/LL</td>
</tr>
<tr>
<td>Boat removal</td>
<td>ERYC</td>
<td>2015 - 2016</td>
<td>FDGiA/LGF/LL</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tidal barrier</td>
<td>EA</td>
<td>2016 - 2018</td>
<td>FDGiA</td>
</tr>
<tr>
<td>Gates</td>
<td>EA</td>
<td>n/a</td>
<td>FDGiA</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H Drain banks</td>
<td>HCC</td>
<td>2016 - 2018</td>
<td>FDGiA/LGF</td>
</tr>
<tr>
<td>G Culvert PS</td>
<td>EA</td>
<td>2016 - 2021</td>
<td>FDGiA/LGF</td>
</tr>
<tr>
<td>E Hull PS</td>
<td>YW</td>
<td>2016 - 2020</td>
<td>FDGiA/LGF</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bransholme PS</td>
<td>YW</td>
<td>Completion 2016</td>
<td>YW</td>
</tr>
<tr>
<td><strong>E</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beverley and Barmston and tributaries banks</td>
<td>ERYC</td>
<td>2020 - tbc</td>
<td>LGF</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hempholme PS</td>
<td>ERYC</td>
<td>2016 - 2018</td>
<td>LGF/ EA revenue</td>
</tr>
<tr>
<td>Wilholme PS</td>
<td>ERYC</td>
<td>2016 - 2018</td>
<td>LGF/ EA revenue</td>
</tr>
<tr>
<td><strong>G</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Flood Management</td>
<td>HCC</td>
<td>2017 - 2019</td>
<td>LGF, Enviro partner</td>
</tr>
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</table>
SECTION 2: INTRODUCTION AND BACKGROUND TO THE STRATEGY

2.1 Introduction

2.1.1 The River Hull Integrated Catchment Strategy (RHICS) was commissioned on behalf of the River Hull Advisory Board (RHAB). The RHAB has been chaired by Graham Stuart MP, and was set up in response to a need to understand drainage and flood risk for all sources within the study area and take forward a framework on behalf of multiple agencies to plan for future activities and investment. The RHICS builds on studies already undertaken, such as the work of Environment Agency’s Draft River Hull Flood Risk Management Strategy (2010) and other studies such as the Hull and Haltemprice Integrated Catchment Model.

2.1.2 The RHAB has membership from the following organisations:

- Members of Parliament
- Member of European Parliament
- East Riding of Yorkshire Council
- Hull City Council
- Yorkshire Water
- Environment Agency
- Beverley and North Holderness Internal Drainage Board
- Natural England
- National Farmers Union
- Community Group Representative
- Regional Flood and Coastal Committee

2.1.3 The RHAB will take forward the development of the RHICS through a multi-agency approach with key stakeholders who have financial, strategic, operational, regulatory or direct day-to-day involvement in flood and water level management activities within the study area.

2.1.4 The RHICS takes into account the requirements of the Water Framework Directive, Strategic Environmental Assessment Directive and other matters. By taking this approach and providing an integrated study of flood risk for the area we are able to provide a

2.1.5 On completion and pursuant to the Flood and Water Management Act 2010 and Flood Risk Regulations 2009 the strategy will inform the Local Flood Risk Management Strategies for both local authorities, Flood Risk Management Plans along with other non-statutory plans and strategies that include or interface with the study area.

2.2 Strategy vision

2.2.1 At the project’s inception, the following vision was agreed by partners:

2.2.2 The River Hull Integrated Catchment Strategy will provide a clearly defined and sustainable multi-agency strategy for the management of flood risk in the natural River Hull valley and support a modified draft River Hull Flood Risk Management Strategy.
Links to other policies and strategies

2.2.3 Primarily, as unitary authorities, Hull City Council and the East Riding of Yorkshire Council are each responsible for producing statutory documents called the Local Flood Risk Management Strategy (LFRMS). These documents, which were at draft stage during the development of RHICS, set out how flood risk should be managed locally. ERYC’s LFRMS was formally adopted by the council on 18th November 2015 and has now become council policy. Other flood risk authorities must have regard to the measures and objectives set out in these strategies. The work undertaken for RHICS helped inform the production of the LFRMS.

2.2.4 As local planning authorities both Hull City Council and East Riding of Yorkshire Council have produced Strategic Flood Risk Assessments (SFRA), which are used to inform the planning process. The Councils have also produced Preliminary Flood Risk Assessments (PFRA) which determined, at a high level, the history and likelihood of flooding. The PFRA identified that one of the catchments of the River Hull valley, the Hull and Haltemprice Catchment, presented a significant risk that was reportable at European Level. As a consequence the Councils are statutorily obliged to produce a Flood Risk Management Plan (FRMP) for this area which sets out the flood risk and interventions required to reduce surface and groundwater flood risk in the catchment. ERYC is producing FRMPs electively for the other catchments, and again these will be informed by the RHICS.

2.2.5 The Environment Agency published and adopted in 2010 the Hull and Coastal Streams Catchment Flood Management Plan (CFMP), including the River Hull Valley area. It defined the broad approach to managing different parts of the River Hull. Recent legislation has made the Agency responsible for FRMPs where there is a risk from river flooding. These management plans are first considered at the Humber Basin Level and subsequently at catchment level in more detail; the plans will use information from and eventually replace CFMPs. The Humber Basin covers one fifth of England, taking in the Trent and Ouse and all their tributaries, and cities such as York, Leeds, Nottingham, Leicester, Derby, Birmingham and Stoke, as well as Hull and Grimsby.

2.2.6 Yorkshire Water Services (YW) produces a five year Asset Management Plan that determines its priorities for investment. This plans must be approved by its regulator Ofwat. Ofwat determines how much money can be raised through bill payers and how investment should be directed. Since 2007 YW has invested c£40m at its three large pumping stations in Hull and is currently investing a further £16m on new pumps at Bransholme pumping station (this investment forms part of the RHICS). Modelling studies are also ongoing with partners to understand the Hull and Haltemprice Catchment in more detail.

2.2.7 There are important linkages between the River Hull Strategy and the Strategic Economic Plans (SEP) prepared by the Local Economic Partnerships (LEPs). Two LEPs cover the catchment; in the north North Yorkshire, York and the East Riding LEP and in the south Hull and Humber LEP, both LEPs recognise flood risk as a barrier to development and consequently support measures to reduce and manage risk. The Humber LEP’s Economic Plan specifically supports the development of the River Hull Integrated Catchment Strategy as many of the aspirations set out in its economic plans are heavily reliant on continued investment in drainage and flood risk infrastructure.
2.3 Background

Location

2.3.1 The study area is located entirely within the ceremonial county in the East Riding of Yorkshire, spanning the unitary local authority districts of East Riding of Yorkshire and Kingston upon Hull. It is one of the most ‘at-risk’, developed flood plains in England. It has a land area of approximately 980 km² and a population of c. 386,000 centred on the large urban area of the city of Hull with the adjoining Haltemprice settlements to the west, along with the principal towns of Beverley and Driffield. The rest of the area is principally rural with a number of smaller dispersed settlements. The River Hull forms part of a complex network of rivers, drains, pumping stations and flood defence banks and walls stretching from above Driffield in the north to the Humber estuary in the south. The network is managed to provide flood protection for around 131,000 properties and round 5,500 hectares of land. The River Hull valley is the second highest flood risk area in the UK.

2.3.2 The RHICS identifies the risk of flooding now and in the future, taking climate change predictions and other factors into account. This strategy details the findings of site work, computer modelling and mapping, along with existing studies in the River Hull valley, to provide options to improve drainage minimise flood risk to an agreed level now and into the future.

Key characteristics and issues of the catchment

2.3.3 The key characteristics are as follows:

a) Much of the study area sits below maximum high tide level relying on extremely complex engineered drainage systems.

b) There are dozens of miles of flood defences along the River Hull and the Humber Estuary that, on a daily basis prevent flooding affecting people, property and land. The defences are what make this area viable.

c) There are multiple types of defences and flood structures in the study area in the valley ranging from raised flood banks in the north to privately owned wharfs in the city; these are in various states of repair.

d) There are five flood Risk Management Authorities that have duties and powers for managing flood risk in the study area; these are Beverley and North Holderness Internal Drainage Board; East Riding of Yorkshire Council; Environment Agency; Hull City Council and Yorkshire Water Services Ltd.

2.3.4 The study area extends from the source of the River Hull in the north near Driffield to its outfall into the Humber Estuary in the City of Hull, a distance of approximately 50km. The river provides a high-level drainage system for waters arising from the Yorkshire Wolds through various streams and becks. Much of the land to the west and east of the river is below high tide level. As such, its water level and drainage is heavily managed, being reliant upon tidal control and pumping operations, similar to the Dutch model and characterised by networks of ditches (cuttings) and raised drainage channels (dykes). It includes the Beverley and Barmston Drain in the west, the Holderness Drain in the east and, in some cases, watercourses and main rivers (large watercourses) that discharge to the public sewerage system.

2.3.5 Engineering works carried out over several hundred years have transformed the former intertidal salt marshes and flood plains into three artificial drainage catchments: the
(upper) River Hull Catchment; the Hull and Haltemprice Catchment (Relevant Flood Risk Area: Flood Risk Regulations 2009); and the Holderness Drain Catchment (see Figure 5). Flows from all three catchments discharge into the Humber estuary either directly, via the River Hull, or from the public sewerage system, through a combination of gravity and/or pumping operations. Local hydrology is influenced by groundwater levels, rainfall events and the tidal effects of the Humber Estuary. This complex arrangement is shown in Figure 2.

2.3.6 Within the study area, all the public RMA’s have existing capital bids from various funding sources for a number of flood alleviation schemes. The funding environment remains challenging; for example the outcome based approach of national FDGiA seeks different outcomes from the growth based LGF. By taking a holistic approach through this strategy there is an opportunity to increase outcomes within limited available budgets. An example of this includes; ERYC identifying a proposed scheme for the village of Leven, and the EA a scheme at Bransholme, as both schemes are hydraulically linked within the catchment a decision has been taken to defer both until the RHICS has come to a conclusion. YW has identified a £170 million investment required in the public sewerage system within the Hull area; funding for these works would be raised through regulated bill payers’ revenues. This investment could achieve further benefits if joined up working through this strategy is undertaken. Between them, the RMAs have almost 90 drainage or flood management schemes at the planning stage.

2.3.7 Partners recognise that the Humber frontage, River Hull (city) defences and the West Hull and Haltemprice surface water schemes are well advanced and should be progressed in tandem with this study and its delivery.
Figure 2 - River Hull schematic map
The draft River Hull Flood Risk Management Strategy (River Hull Strategy) was published for consultation in May 2010 following a technical, environmental and economic appraisal study. Significant concerns were raised about the study by local RMAs and key stakeholders, who were not able to endorse or support the proposed Strategy. The study did not fully take into account the inter-relationship with other sources of flood risk in the natural River Hull valley which are complex, varied and known to have a significant impact. The report relied on evidence produced using standard methodology, assumptions and boundary conditions for fluvial flooding, for these reasons some RMAs were unable to give technical endorsement. In November 2012 observed flooding confirmed anomalies in the existing study.

Fundamentally, a large expanse of the inland catchment acts as a ‘sponge’, attenuating flows to reduce flooding, so when considering the intervention or benefits the project board agreed it was appropriate to analyse the entire study area, as opposed to just the valley floor, and in order to give confidence the study would compare spatial depth prediction of observed events against a new model.

Compared to the previous study, sensitivity analysis undertaken as part of the RHICS suggests an under-prediction in flood extent of approximately 100 ha to the north of the City, and an additional 50 ha of flooding in urban areas outside of the City. This analysis brings a further c2000 properties into the ‘at risk’ area. It is noted that these additional areas of flooding are located near smaller ordinary watercourses/drains, and it is likely that the resolution of the previous study meant many of these areas were not well represented. An example of this effect is that in the 2007 floods it appears that flooding in Bransholme was exacerbated by flood waters passing from the Holderness Drain back through Crofts Drain; this was not picked up in the original study.

Because drainage systems are tidally locked, with much of the valley floor in a range 0-5m AOD, flood risk is heavily influenced by antecedent conditions. An assessment of climatic antecedents was undertaken for the EA River Hull Strategy model; however, this lacked further analysis through methodologies such as PROPWET and SPR coefficients when applying ReFEH calculations for point hydrological sources.

The present combination of joint probabilities utilised for fluvial and base-flow likely led to an underestimate of flows, with an additional 10m³/s alone accreted groundwater flow available at the Humber boundary if a 1 in 2 year groundwater flow is combined with a 1%AEP fluvial flow.

Surface water flooding was under-predicted, particularly in urban areas such as the outskirts of the city, Beverley and Driffield etc. This was likely to be due to the representation of overland flow emanating from the river model only, which is largely driven by flow inputs as opposed to direct rainfall and the use of a suitable ground infiltration model.

The Yorkshire Water combined sewer and surface water networks provide preferential conduits for flood waters to discharge to watercourses, including a major trunk sewer network that has a combined capacity able to transfer in excess of 50m³/s. Flooding through ancillary drainage apparatus can occur under flood events, greatly affecting downstream areas. The assumptions and storm events used in the modelling for the EA River Hull Strategy followed standard guidance, and considered single storm events for

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3 Above Ordnance Datum – spot measure of mean sea level taken at Newlyn, Cornwall.
4 Annual Exceedance Probability – is the chance of a flooding event occurring annually represented as a percentage.
fluvial flooding. However, as seen in the 2007 floods, and more recently in the winter of 2012/13, contiguous storm events present a more realistic, significant and different combined flooding risk for the study area, especially when taking other inter-related sources of flood risk into account.

2.3.15 Existing infrastructure in the study area is operated and maintained by different agencies and, in some cases, the functionality of some assets serves more than one source of flood risk. For example, at East Hull Pumping Station, the public sewerage function is provided by YW and the flood risk function by EA.

2.3.16 Currently, planned changes to various infrastructure by the different RMAs is considered on an individual basis and does not always recognise the wider impact of linked hydrology. Examples did include the proposed changes by YW at Bransholme Surface Water Pumping Station to deal with an increase in surface water flows from the Kingswood development, and EA proposals for dealing with flows in the Holderness Drain and Bransholme area; these measures are now considered holistically within this strategy.

2.3.17 Without a co-ordinated multi-agency approach, it is considered that potential opportunities for efficiencies by prioritising future maintenance and investment from the various RMAs in a cost-effective and integrated way will be missed. More pressing is the need to avoid inappropriate interventions.

**Multi-agency strategic approach**

2.3.18 Following representations from RMAs, residents and businesses, Graham Stuart, Member of Parliament (MP) for Beverley and North Holderness, established the RHAB. The board’s members are identified in 2.1 above.

2.3.19 The purpose of the RHAB is to provide a holistic approach for the management of flood risk now and into the future. This approach is supported by all the RMAs.

2.3.20 This RHICS will be delivered through a multi-agency officer Project Board representing all of the RMAs in the study area, together with Natural England, who have financial, strategic, operational and regulatory or direct day-to-day involvement in flood and water level management activities. The project is administered by East Riding of Yorkshire Council.

2.3.21 Contributions have been sought from each of the key stakeholders towards the £732,900 cost of the study as follows:

A) ERYC - £270,400 plus £62,500 project risk
B) Beverley and North Holderness IDB - £15,000
C) Hull City Council - £35,000
D) Yorkshire Water - £25,000
E) Yorkshire Regional Flood and Coastal Committees (RFCC) - £125,000 (linked to Grant in Aid approval process)
F) Defra National Flood Defence Grant - £200,000

2.4 **Aims and objectives**

2.4.1 Our overall aim is

*To provide a sustainable flood risk management strategy for the River Hull catchment over the next 100 years.*
2.4.2 The study provides a clearly defined and sustainable multi-agency strategy for the management of flood risk in the natural River Hull valley and supports a modified draft EA River Hull Flood Risk Management Strategy.

2.4.3 To ensure that all the RMAs are able to support the outcome the Advisory Board has adopted the following Acceptance Criteria:

a) The Advisory Board accepts the recommendations and outcome of this project can be taken as robust and credible evidence which will be used to modify the outputs of the EA Strategy, and to inform current and future Flood Risk Management Strategies and Plans.

b) The Advisory Board considers that an appropriate level of local community engagement has taken place.

c) The Advisory Board considers that an appropriate level of funding will be made by all Partners to the RHICS Project and that reasonable efforts to secure the most appropriate economic methods for capital investment and revenue maintenance have been undertaken and accepts the recommended proposals arising from the options appraisal and reviewed maintenance activities based on these methods.

d) The Advisory Board accepts that all Partners are willing to consider and accept the optimal use of flood risk assets for the wider benefits in the River Hull valley (* relating specifically to flood risk benefits).

e) The Advisory Board considers that the findings of this project are both practicable and deliverable and will include for an agreed multi-agency investment plan that has specific projects and timescales in the short, medium and long term and that Partners will commit quickly to developing schemes to mitigate flood risk.

2.4.4 And the following strategic objectives:

i) Identify the optimum sustainable approach, working in partnership to produce a more efficient process of integrated management of flooding risk across the natural River Hull valley.

ii) Identify and prioritise other flood risk management activities such as providing advice for future spatial planning and resilience through the protection of important utility infrastructure.

iii) Identify and prioritise the associated funding approach for project implementation over the next 20 years and longer term.

iv) Using the multiple benefit approach taken in the strategy to seek opportunities for additional sources of funding.

v) Minimise adverse impact caused by Strategy recommendations and seek ways to enhance the environmental, amenity and recreational value of the study area and contribute to the delivery of recommendations in the River Basin Management Plan (RBMP).
Using these strategic objectives, we have developed the *sustainable development objectives* above that will guide RHICS over the agreed delivery period and allow us to monitor progress and measure achievement.
<table>
<thead>
<tr>
<th>Economic Objective</th>
<th>Sub-Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood protection</td>
<td>Protect people and property by providing the required flood management solutions to reduce surface water and river flooding risk within the River Hull catchment</td>
</tr>
<tr>
<td>System effectiveness</td>
<td>Ensure adequate maintenance of or improve water management and flood risk assets so the catchment network is efficient, effective and safe</td>
</tr>
<tr>
<td>Economic development</td>
<td>Help to realise the potential of industrial or commercial activities where it was previously non-existent or stagnated due to the associated flood risk Continue to inform and assure investors about the actual risk of flooding alongside works that are ongoing and proposed</td>
</tr>
<tr>
<td>Housing development</td>
<td>Help ensure development of new housing which takes account of and builds in resilience to flood risk</td>
</tr>
<tr>
<td>Agricultural production</td>
<td>Reduce the vulnerability of agricultural land to flooding and help promote food security so it can reach its full productive potential Promote farm crop (including biofuel crops) and habitat diversification and on-farm microgeneration opportunities to help achieve natural attenuation and reduce run-off</td>
</tr>
<tr>
<td>Information provision</td>
<td>Provide accurate information to enable insurers and developers to be better informed about the degree of flooding</td>
</tr>
<tr>
<td>Tourism and recreation</td>
<td>Help improve tourism, amenity and recreational opportunities by reducing their flood risk and improving their flood resilience</td>
</tr>
<tr>
<td>Water resources</td>
<td>Protect water quantity and quality for abstraction and supply</td>
</tr>
<tr>
<td>Social objectives</td>
<td>Sub-Objective</td>
</tr>
<tr>
<td>Health and wellbeing</td>
<td>Help reduce the psychological impact of flooding on people by reducing flood risks</td>
</tr>
<tr>
<td>Transport and infrastructure</td>
<td>Prevent adverse impacts of flooding on communication links and energy supply</td>
</tr>
<tr>
<td>Water Framework Directive</td>
<td>Help bring water bodies to a good state of health so they can be used for social, economic and environmental purposes</td>
</tr>
<tr>
<td>Cultural heritage</td>
<td>Prevent damage to designated assets within the catchment Help discover and record new heritage features and assets by careful management of works</td>
</tr>
<tr>
<td>Environmental objective</td>
<td>Sub-Objective</td>
</tr>
<tr>
<td>Landscape</td>
<td>Support and promote land use change that reduces flood risk and promotes improved landscape character</td>
</tr>
<tr>
<td>Habitats and species</td>
<td>Avoid damage to designated sites and contribute towards their enhancement Promote the favourable condition of SSSIs and other hydrologically sensitive sites though careful water management Contribute to relevant UK and local BAP habitats and species targets though strategy actions</td>
</tr>
<tr>
<td>Fisheries</td>
<td>Help promote a natural and self-sustaining riverine fishery</td>
</tr>
<tr>
<td>Climate change</td>
<td>Ensure that flood risk management solutions are resilient to the predicted effects of climate change</td>
</tr>
</tbody>
</table>
2.5 Governance

2.5.1 The RHICS is administered by the RHICS Project Board (the project board) ensuring that all relevant stakeholders are consulted. The project board is made up of technical and managerial officers from the RMAs that have statutory and permissive responsibilities in the study area. The board operates within agreed and approved terms of reference, and advises and receives advice from the RHAB by exception or on a quarterly basis.

2.5.2 Progress, exception reporting and decision-making is supported by the Project Board on a monthly basis where delegated authority is given to those officers. Key decisions and final approval are made by the RMAs respective approval bodies or delegated to an officer, e.g. (Area Flood and Coastal Risk Manager (EA), Cabinet (Local authority (LAs)), a

Figure 3- Project governance
heir responsibilities, are:

Environment Agency
The EA has local responsibilities for managing flood risk from rivers and sea and manages FGDsA on behalf of Defra through an approved assurance framework. Having published its draft FRMS in May 2010, the EA has agreed that this strategy be deferred until the publication of the RHICS. The EA has been able to bring considerable expertise and support to this process. It is statutorily obliged to produce Flood Risk Management Plans (FRMPs) for river systems. The RHICS will inform these plans and is cross referenced in current draft plans. The EA is a Category 1 Responder for the emergency planning and response.

East Riding of Yorkshire and the Hull City Councils
The Councils are the Lead Local Flood Authorities for their districts with statutory duties to develop an overarching Local Flood Risk Management Strategies (LFRMS) and statutory FRMPs for surface and groundwater flooding (including public sewers) which shall be informed by the RHICS. With relevance to the RHICS they are also a Land Drainage Authority, Local Planning Authority, Highway Authority, Public Health Authority and a Category 1 Responder for the emergency planning and response.

Beverley and North Holderness Internal Drainage Board
The BNHIDB is administered by the York Consortium of Drainage Boards and manages a series of board-maintained watercourses and ancillary apparatus in the River Hull valley. It is the Land Drainage Authority for much of the rural area within the River Hull Valley with certain permissive powers and duties, both made through national legislation and bylaws.

Yorkshire Water Services Limited
YW is the statutory sewerage undertaker within the entire study area meaning it manages the public sewerage system including ancillary assets such as the East Hull Pumping Station. It has been able to contribute a significant amount of empirical data to the study through its investment in hydraulic models of the urban area. YW is also the statutory water undertaker with a duty to supply drinking water that is safe and of a quality acceptable to consumers. It is a Category 2 Responder for the emergency planning and response.

2.5.4 The following stakeholders are also consulted:

Community Group
The success of the project has relied heavily on inputs and acceptance from the local community, to both test the assumptions of professionals and support the project with good local information. It also important to consider and appreciate the community’s expectations and understanding of flood risk.
A Community Group was established as a forum for stakeholder and community representatives to share, challenge, debate, influence, and communicate the progress and development of the project. A core group of interested individuals developed out of the wider group, representing residents, business, farming and landowner interests. They have been active in the past, including from the consultation process for the EA River Hull Strategy.

Ward Members
Ward Members are the elected representatives of residents so it is important to ensure they are kept informed and their opinions considered during the development of the strategy. Together with the Community Group their support has been garnered for the wider public communication plan.
Heritage England and the Humber Archaeology Partnership

HE is a statutory consultee and offers national advice on cultural heritage issues. HAP is the local joint partnership with a wealth of local expertise and knowledge. It liaises closely with HE. Both have been consulted as part of the development of RHICS and its SEA. They will continue to be involved as projects develop to take account of any proposed changes that may impact on the archaeology in the River Hull valley.

Natural England

NE is a statutory consultee and a key environmental stakeholder, and is represented on the project’s Advisory Board. The project board has consulted with NE on work already completed in the study, and as part of the SEA process, to take account of any proposed changes and measures that may impact on the natural environment or be required. It will be a key partner as upland attenuation proposals are developed further. It has also become a member of the Project Board to help ensure the strategy and project delivery meet statutory duties to protect, conserve and enhance habitats and species, and has been particularly closely involved in the project’s Habitat Regulations and Strategic Environmental Assessments.

Other stakeholders

As part of the consultation process on strategy development a broad range of community, business, and environmental organisations has being consulted. Reports and schedules of consultation comments have been prepared and placed on the RHICS web page. In addition a list of ‘statutory consultees’ has been consulted, based on the lists retained and used by the EA and the two local authorities planning teams.

2.6 The study rationale

2.6.1 The draft Environment Agency River Hull Flood Risk Management Strategy (River Hull FRMS) was published for consultation in May 2010 following a technical, environmental and economic appraisal study. Significant concerns were raised about the study evidence by local Risk Management Authorities and key stakeholders, who were not able to endorse or support the proposed strategy.

2.6.2 The main concerns raised were:

2.6.3 The FRMS did not take account of the inter-relationship with other sources of flood risk in the natural River Hull valley which is complex, varied and known to have a significant impact. The study used standard methodology, assumptions and boundary conditions for fluvial flooding; in so doing its evidence was insufficient to be validated from known flooding events.

2.6.4 The FRMS concluded that catchments could be evaluated independently using main river ID and 2D modelling. However, a large expanse of the inland catchment acts as a ‘sponge’, attenuating flows to reduce flooding in the city. It was considered more appropriate to view the catchment as a whole for flood protection.

2.6.5 The River Hull strategy model spatial predictions did not match the recorded flooding of 2007. This is evidenced in the north of Hull around Bransholme to the east, and Dunsowell/Orchard Park areas to the west also in the upper Hull catchment around Beverley, Driffield, Leven.

2.6.6 An initial sensitivity analysis suggested that this mismatch indicated a wider area at flood risk: approximately 100 ha to the north of the City, and an additional 50 ha of urban
areas in the upper catchment, bringing a further 2,000 properties into the ‘at risk’ area. Such areas were not well represented in the FRMS due to the fact they are located near smaller ordinary watercourses and drains. The modelling used a higher resolution of detail for the main rivers and drains, however the large complex network of smaller watercourses wasn’t represented to the same level.

2.6.7 Flooding in the study area is influenced greatly by antecedent conditions. An assessment of such antecedent conditions was carried out in the FRMS model, but required further analysis through the use of PROPWET and SPR coefficients when applying ReFEH calculations for point hydrological sources.

2.6.8 The combination of joint probabilities utilised for fluvial and baseflow in could have led to an underestimate of flows, for example an additional 10m³/s alone accreted groundwater flow available at the Humber boundary if a 1 in 2 year groundwater flow is combined with a 1%AEP fluvial flow.

2.6.9 Surface water flooding was under-predicted, particularly in urban areas such as the outskirts of the city of Hull, Beverley and Driffield. The overland flow was represented as emanating from the river model only largely driven by flow inputs, and not from direct rainfall falling and the use of a suitable ground infiltration model.

2.6.10 Yorkshire Water’s combined sewer and surface water networks provide preferential conduits for flood waters to discharge to watercourses, including a major trunk sewer network that has a combined capacity able to transfer in excess of 50m³/s. Flooding through manhole discharges occurs under extreme flood events, greatly affecting downstream areas.

2.6.11 The assumptions and storm events used in the modelling for the FRMS followed standard guidance, and considered single storm events for fluvial flooding. However, as seen in the 2007 floods, and more recently in the winter of 2012/13, contiguous storm events present a more significant and different combined flooding risk for the River Hull valley, especially when taking the other inter-related sources of flooding risk into account.

2.6.12 A co-ordinated multi-agency approach is considered essential as:

1) *Existing infrastructure in the catchments is operated and maintained by different agencies and, in some cases, the functionality of some assets serves more than one source of flooding risk (e.g. East Hull pumping station)*

2) *Planned changes to various infrastructure by the different Risk Management Authorities (RMAs) is considered on an individual basis and does not always recognise the wider impact on the other inter-related sources of flooding risk*

3) *Potential opportunities for efficiencies by prioritising future maintenance and investment from the various RMAs in a cost-effective and integrated way will be missed. There is the need to avoid inappropriate interventions.*

2.7 **Strategy development approach**

2.7.1 When considering how to build upon the work undertaken for the EA’s 2010 River Hull FRMS, four different approaches were analysed. Please note that these were options for developing the Strategy Approach and NOT an economic assessment.
Option 1: Do nothing

2.7.2 Under this option, there would be no strategy and the reduction of existing flooding risks would be reliant on a range of mutually exclusive schemes. The system would be maintained with partners pursuing individual schemes within their respective responsibilities.

2.7.3 Advantages:
   a) No additional expenditure on developing the River Hull Strategy
   b) Can be implemented immediately

2.7.4 Disadvantages:
   a) There would be no agreed strategy for the River Hull valley providing a coordinated approach to all sources of flood risk
   b) Expenditure committed to date on the River Hull Strategy would not provide an agreed output
   c) The cumulative benefit of the individual scheme investments may not be cost-effective
   d) Flooding still occurs in an unpredictable manner, and is dealt with on an ad-hoc and piecemeal way
   e) The impact of the individual schemes may increase or transfer the level of flood risk in parts of the river valley
   f) There is a reputational risk if flooding events occur after completion of the individual schemes
   g) This would not meet the requirements of key stakeholders on the RHAB and their expectation that the scope of the River Hull Strategy is to be broadened
   h) The opportunity of developing an integrated strategy through multi-agency working will be missed
   i) It will not deliver a long-term prioritised partnership funding strategy.

Option 2: Adopt the EA River Hull Strategy

2.7.5 Under this option, the existing River Hull Strategy would be adopted unchanged.

2.7.6 Advantages:
   a) Expenditure committed to date on the River Hull strategy would provide an output
   b) No further expenditure on developing the existing River Hull Strategy.

2.7.7 Disadvantages:
   a) No coordinated approach to the management of flood risk
   b) The strategy recommendation is based on data that is limited to fluvial flooding
   c) The standard modelling approach has produced data that does not match actual flooding events
   d) There is a risk that the flooding extent is greater or different to the modelled evidence
   e) No account has been taken of the impact on the other sources of flooding risk
   f) The cumulative benefit of individual scheme investments may not be cost-effective
g) The impact of individual schemes may increase or transfer the level of flood risk in parts of the river valley
h) There is a reputational risk if flooding events occur after implementation of the River Hull strategy
i) This would not meet the requirements of the RHAB and the expectation that the scope of the River Hull Strategy is to be broadened
j) The opportunity of developing an integrated strategy through multi-agency working will be missed
k) It will not deliver a long term prioritised partnership funding strategy
l) None of ERYC's and BNHIDB's concerns would be addressed.

Option 3: Review the EA River Hull Strategy

2.7.8 Under this option, the existing EA hydraulic model would be reviewed with updated assumptions and boundary conditions.

2.7.9 Advantages:

a) Expenditure committed to date on the River Hull strategy would provide an output
b) Updated evidence would be produced using new boundary conditions and assumptions
c) The range of options could be reviewed against the updated evidence
d) Takes a wider view of possible flood risk management solutions

2.7.10 Disadvantages:

a) There will be additional expenditure to review the study
b) Implementation of the EA River Hull Strategy will be delayed
c) The strategy would be limited to fluvial flooding
d) The revised data may not match actual flooding events
e) No account has been taken of the impact on the other sources of flooding risk
f) There is a risk that the flooding extent is greater or different to the re-modelled evidence
g) The cumulative benefit of individual scheme investments may not be cost effective
h) The impact of individual schemes may increase or transfer the level of flood risk in parts of the river valley
i) There is a reputational risk if flooding events occur after implementation of a reviewed River Hull strategy
j) This would not meet the requirements of the RHAB and the expectation that the scope of the River Hull Strategy is to be broadened
k) The opportunity of developing a fully an integrated strategy through multi-agency working will be missed
l) It is unlikely that ERYC and BNHIDB could accept a partially reviewed and updated EA River Hull Strategy that failed to address all their concerns.

Option 4: Develop an Integrated Catchment Strategy

2.7.11 Under this option, data would be taken from the River Hull Strategy and other studies and would be broadened to cover the management of water levels and flood risk from all sources in the natural River Hull valley.
2.7.12 Advantages:

a) Expenditure committed to date on the River Hull strategy would provide an output

b) An agreed strategy for the River Hull catchment for all sources of flood risk acceptable to all Risk Management Authorities and communities

c) Opportunities for different funding streams through the acceptance of the evidence in the Strategy

d) Incorporate work for the LEP on ecosystems services appraisal in line with Defra guidance about including ecosystems within the economic appraisal

e) Opens up opportunities to incorporate in LA capital programme potentially releasing European Union Structural and Investment fund (EUSIF) and growth funding through the LEP

f) Aligns strategy to Water Framework Directive (WFD) agenda

g) Updated evidence would be produced using new boundary conditions and assumptions.

h) The range of options could be reviewed against the updated evidence

i) The scope of the strategy would be broadened to take account of the impact of other sources of flooding risk

j) A range of options can be considered and appraised against the updated evidence

k) An integrated approach and modelling capability will be produced

l) The cumulative benefit and impact of the individual scheme investments can be considered

m) Schemes can be packaged and efficiencies found by producing innovative ideas that are multi funded and multi beneficial

n) The impact of the individual schemes on the flood risk in other parts of the river valley can be assessed

o) There will be an opportunity of developing an integrated strategy through multi-agency working.

p) It will deliver a long term prioritised partnership funding strategy.

2.7.13 Disadvantages:

a) There will be additional Grant-in-Aid expenditure to review the study

b) Implementation of the EA River Hull Strategy will be delayed

c) There is a reputational risk if flooding events occur after implementation of a reviewed River Hull strategy, though this could be less likely

d) Potential affordability issues.

Preferred option

2.7.14 The preferred option was Option 4 - to develop a new Integrated Catchment Strategy. This option ensured the scope was broadened to cover the management of water levels and flood risk from all sources in the natural River Hull valley providing an integrated strategy and a prioritised funding strategy.

2.8 Study plan and strategy development
2.8.1 The study plan broadened and developed the work already completed for the EA River Hull Strategy as summarised below.

2.8.2 The strategy has been developed in a number of stages:

1. Strategy procurement
2. Hydraulic modelling
3. Baseline understanding
4. Strategy development and appraisal
5. Preferred management strategy documentation and submission

2.8.3 Strategy development at all stages follows the Flood and Coastal Erosion Risk Management Appraisal Guidance. Technical inputs have been carried out using appropriate British or International Standards or Best Practice Guidance. Economic assessment follows the recommendations of FCERM-AG and the MCM 2013.

**Strategy procurement**

2.8.4 Strategy procurement has been undertaken by East Riding of Yorkshire Council via the YORconsult contract framework. Four consultancy firms shared the contracted work in a number of separate fields.

**Hydraulic modelling**

2.8.5 The first stage of the plan was to establish the quality and resolution of existing computer models for the various sources of flood risk within the various catchments. These were assessed against the needs of an integrated modelling capability, and specifications produced for the development of additional modelling capability.
2.8.6 In discussion with the consultants for the EA River Hull hydraulic model, YW sewerage models and Local Authority surface water models, the boundary conditions, assumptions, and data previously used was reviewed, and a programme of survey work to collect and collate it was developed.

2.8.7 Additional watercourse details were included in the ICM flood model and inflows reassigned. The sensitivity of the flooding predictions to point source baseflow values was also incorporated into the revised ICM model, utilising a 2D ground infiltration model. This model utilised a Hortonian infiltration model with flows decreasing to a potentially low value when the sub-soil regime wets-up, thereby causing runoff.

2.8.8 The proposed boundary conditions, design storm specification, antecedents (reference November 2012) and other conditions (e.g. climate change) to be used for the integrated strategy were developed further and submitted for agreement and approval by all the stakeholders. Completion of this stage produced an integrated modelling capability that simulated the combined impacts from the various sources of flooding risk over a range of scenarios.

Baseline understanding

2.8.9 During the development of the integrated hydraulic modelling capability, all the existing technical and environmental reports and associated documents produced as part of the study for the EA River Hull Strategy were reviewed to understand the work that was previously undertaken. These were developed further to include for the wider scope of surface, ground water and networks flood risk, and a plan developed for delivery.

2.8.10 Once all the updated information was produced, it was collated with the hydraulic modelling outputs to re-define the baseline position for the combined impacts of surface, ground water and networks flood risk.

Economic appraisal

2.8.11 The standard Defra economic appraisal carried out for the River Hull Strategy was updated to comply with the 2013 edition of Defra’s Multi Coloured Manual to re-establish the baseline position, and further costs associated with the impacts on other existing or planned major infrastructure in the valley were built in, recognising the changes that have been made or are planned since the original study was carried out. Section 6 details how this was developed.

Strategy development

2.8.12 The preferred approach from the EA’s 2010 River Hull FRM Strategy was reviewed against the updated evidence to evaluate its performance and, if required, modified or an alternative strategic option developed, to mitigate the evidenced combined flood risk.

2.8.13 In line with the procurement strategy the following task approach was used through the life of the RHICS:

i) Technical - to include method benefits, limitations, constructability;
ii) Economic - benefit/cost appraisal of whole-life costs, partnership funding opportunities;
iii) Environmental - assessment of environmental impacts and/or enhancements, compliance with WFD/FD.
iv) Risk - assessment of any residual risks, or potential future risks.
2.8.14 A cost-benefit appraisal of each option has been carried out together with an economic assessment in accordance with the FCERM-AG and the MCM 2013 to establish the cost benefit and ensure the recommended solution gives an affordable and acceptable level of protection. Particular attention has been given to the agricultural valuation to ensure it follows Defra guidance and to the splitting of benefits between different sources of flooding, which follows the methodology agreed by East Riding of Yorkshire Council, Hull City Council and the EA for other Hull FRM projects. Section 6 below details the appraisal process and parameters used.

2.8.15 Recognising the complexities across the wider catchment, the project board commissioned the services of Dr John Chatterton who has supported this appraisal to ensure it is consistent with accepted policies. Alternative sources of funding (other than FDGiA) that may be available to the strategy area are identified within the strategy and early engagement with potential Partnership Funding (PF) contributors to ensure they are aware of the strategy process being undertaken.

Environmental assessment

2.8.16 Partners consider that RHICS requires a Strategic Environmental Assessment (SEA). Following discussions, the approach taken has been to use the EA’s comprehensive SEA from its draft 2010 River Hull strategy and add new work where identified as necessary. An allowance was made for a Habitat Regulations Assessment to be undertaken should the SEA identify potential adverse impacts of RHICS proposals on the Humber’s statutory wildlife designations. In due course the SEA did reach such a conclusion, and an HRA was commissioned. Section 8 provides more details of the assessment findings, and the SEA’s and HRA’s recommendations have been built into each option assessment in Section 9.

Management strategy documentation

2.8.17 On behalf of the Advisory Board the project executive produced a ‘Preferred Approach’ draft strategy document in November 2014. It was based on an early draft of this full strategy. The Advisory Board approved the Preferred Approach documents as a basis for wider consultation and engagement. The approval of the Preferred Approach draft strategy and the consultation process by the five RMA’s boards or committees was obtained in November and December 2014.

2.8.18 A mobile exhibition vehicle, dubbed the “Floodbus”, was used to host a series of outdoor information events held in Beverley Saturday Market (29th November), Hull Queen Victoria Square (4 December), and Driffield Middle St South (6 December). An event was held at County Hall Beverley on 5 December for an invited audience of ward and parish councillors, and business, resident and environmental groups from across the study area. Media was produced for these events including information boards and audio visual presentations. Presentations have also been made to a number of partnership groups, such as the East Riding Rural Partnership, NFU and BNHIDB. Local news media have carried reports on a regular basis, including interviews to camera for BBC’s Look North. These have helped raise awareness of flood risk and development of the joint approach.

2.8.19 On behalf of partners the East Riding of Yorkshire Council has hosted the Preferred Approach draft strategy document on its website (www.eastriding.gov.uk/riverhull), together with a series of videos – an example of water injection dredging, and an animation flyover of the river from Beverley to Tickton to highlight sunken vessels and channel narrowing. A long list of sub-regional, regional and national bodies were alerted to the Preferred Approach, and invited to comment. The consultee list was aggregated from that of the two local planning authorities and that used by the EA for its 2009
consultation exercise. A report on consultation comments was presented to the Advisory Board on 30 January 2015 and appropriate changes made.

2.8.20 A more focused consultation was undertaken with statutory consultees, environmental groups and the archaeology partnership on the SEA and HRA in late May 2015. Schedules of comments are also available via the ERYC flood risk website.

Risks to delivery

2.8.21 The following risks to the successful delivery of the Integrated Catchment Strategy were identified at project initiation and are summarised below:

a) Programme - Delays to the strategy can be caused due to stakeholder consultation and statutory consultee consultation and approvals. These risks are to be mitigated by the use of a multi-agency approach and focussed Community Group to support and advise the project team during the development of the strategy.

b) Stakeholder agreement - To ensure that all the stakeholders are tied into the outcome and support the modified strategy, project acceptance criteria previously approved at the project launch have been developed for approval by the River Hull Advisory Board meeting on 24 January 2014.

c) Environment impact - Presentation of options which would be unacceptable due to the environmental impact will be assessed during the strategy and alternatives would be suggested. If required mitigation of residual environmental impacts would be proposed in the updated Strategic Environmental Assessment. Natural England’s local team are key advisors.

d) Changes to project assurance and guidance - Changes to FCERM-AG or other funders’ assurance systems. This can be mitigated through on-going liaison with the Environment Agency and other funders.
SECTION 3: CATCHMENT OVERVIEW

This section describes the RHICS study area. It includes:

a) A brief description of the catchment of the River Hull, tributaries and associated drainage system, and a definition of the boundary of the study area.
b) A summary of the environmental issues, drawing on the Strategic Environmental Assessment process
c) Identification and assessment of flood risk and flood risk management options
d) An explanation of the links with other plans and policies, and where these may provide opportunities or present constraints.

3.1 River Hull catchment and study area

Study area

3.1.1 The RHICS location and study area is shown in Figure 5. The study area covers approximately 980 km², with the Yorkshire Wolds to the west and north and the Humber Estuary to the south. There are 3 distinct hydraulic catchments in study area: these are the (upper) River Hull, Holderness Drain, and Hull and Haltemprice. These catchments fall within the administrative areas of Hull City Council, East Riding of Yorkshire Council and a small area of Ryedale District Council and North Yorkshire County Council. Hull is the main urban centre within the study area. Other principal settlements within the catchment include the market towns of Beverley and Driffield, there a number of villages and small dispersed settlements.
Table 4 below, provides a summary of the key physical and environmental features of the Strategy area. This should be used as an approximate overview of the catchment,

<table>
<thead>
<tr>
<th>Table 5 - RHICS area overview (Environment Agency, 2010)</th>
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<tbody>
<tr>
<td><strong>Watercourse</strong></td>
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<tr>
<td>233 km designated as main rivers</td>
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<tr>
<td><strong>Average annual rainfall</strong></td>
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<tr>
<td>Between 625 to 825mm</td>
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<tr>
<td><strong>Urban areas</strong></td>
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<tr>
<td>Kingston-Upon-Hull, Beverley, Driffield</td>
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<tr>
<td><strong>Assets</strong></td>
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<tr>
<td><strong>Total for Strategy area</strong></td>
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<tr>
<td><strong>At Risk of flooding</strong></td>
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<tr>
<td><strong>At risk of flooding (%)</strong></td>
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<tr>
<td>Population</td>
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<tr>
<td>386,000</td>
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<td>217,000</td>
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<tr>
<td>56</td>
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<tr>
<td>Area</td>
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<td>980 km²</td>
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<td>Agricultural grade land (1.3)</td>
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<td>11</td>
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<td>Canals</td>
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<tr>
<td>7.5 km</td>
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<td>56</td>
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<tr>
<td>Sites of Special Scientific Interest (SSSIs) (ha)</td>
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<td>415 ha</td>
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<tr>
<td>66 ha</td>
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<tr>
<td>16</td>
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<tr>
<td>Schedule Monuments (SMs) (number)</td>
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<td>185</td>
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<td>6</td>
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</tbody>
</table>

*Based on 1% Annual Exceedance Probability (AEP) fluvial flood extent for the River Hull and Holderness Drain system if flood defences are not present (based on future climate), this does not include smaller areas of more localised flooding on smaller tributaries away from the main river valley.

the derivation of the ‘at risk of flooding’ values is discussed in Section 4.

**Topography**

3.1.3 Topography (the surface shape and features) has a direct impact on flood risk through its influence on catchment response to rainfall. Steeper slopes tend to cause a faster speed of flow, both below and over the ground surface. Topography also influences the extent of flooding as in flat areas floodwaters can spread over much larger extents than in narrow valleys; this is of particular note in the study area.

3.1.4 The land in the RHICS area rises from mean sea level (or just below) to nearly 250m above sea level (Figure 6). The highest land is in the Yorkshire Wolds, which runs in an arc across the north and west. The topography of the Wolds escarpment is typical of chalk landscapes with a gently rolling plateau that falls gradually eastward towards the Holderness Plain. A complex network of often steep-sided and deep valleys run out of the Wolds to the low lying areas.

3.1.5 Away from the Wolds the remainder of the River Hull Strategy area is dominated by flat and low lying land which includes the plain of Holderness to the east. The Holderness plain largely consists of superficial glacial till that rises gently to the coast meaning the
drainage systems flow away from the coast towards the river Hull valley floor. Much of the valley floor is at or below mean sea level.

3.1.6 The River Hull

Figure 6 - LiDAR map of the study area

Figure 7 - Longitudinal section of the River Hull
Hull has almost no gradient in the middle and lower reaches with the tidal influence extending up to Hempholm Weir, around 30 km upstream of the Humber. A section of the River Hull is shown in Figure 7 below, including differing event heights.

Geology and hydrogeology

3.1.7 The geological map for the study area (Sheet 72, Beverley, 1:50,000, Solid and Drift Edition, 1995) indicates that the study area is directly underlain entirely by units of the Flamborough Chalk Formation to the north of Cottingham and by the Welton and Burnham Chalk Formation to the south of Cottingham. These are overlaid by superficial deposits predominantly comprised of alluvial and estuarine clay and silt. Localised areas of glacial till are also shown occupying more topographically elevated areas along the banks of the River Hull together with isolated pockets of glacio-fluvial sand and gravel. Figure 8 shows the superficial deposits.

3.1.8 With reference to the groundwater vulnerability maps available on the Environment Agency website, the superficial deposits overlying most of the study area are generally classified as a 'Secondary B Aquifer' as the Estuarine and Alluvial clay and silt are low permeability soils with limited capacity to store or transmit groundwater other than via thin permeable layers. The Chalk strata are classified as a 'Principal Aquifer' as a result of the fracture permeability of Chalk which provides a high level of groundwater storage, producing good quality drinking water. Due to the presence of a drinking water extraction boreholes at Dunswell, Cottingham and Willerby the chalk aquifer beneath this part of the study area is within a Groundwater Source Protection (GSP) Zone 1 in Figure 9 below. Much of the catchment is now within a new outer Zone 3 (see figure 9 below). Of particular note is the Option 4 Downstream Storage Area which is in part located in the GSP Outer Zone 2 and it is generally an Environment Agency requirement that all flood water storage lagoons in a GSP Zone 2 are lined with a layer of low permeability (1x10^-9 m/s) clay.

3.1.9 The definitions for each of the zones can be found at http://apps.environment-agency.gov.uk/wiyby/37833.aspx.
The River Hull is fed by a number of springs (kelds) and becks within the Yorkshire Wolds, which join together south of Driffield. The river flows through open countryside before it skirts past the eastern edge of the town of Beverley and reaches Hull. It flows through the centre of the heavily populated and industrial area of the City of Hull before joining the Humber estuary at Victoria Pier near to The Deep and the Tidal Surge Barrier (TSB). The River Hull is embanked (dyked) for most of its length in order to achieve an engineered gradient; in some places the embankments are up to 5m high and in places the bed of the river is above the level of the surrounding land.

The river is generally regarded as tidal up to Struncheon Hill Lock/Hempholme Weir, but historically tidal influence has been up to the former Snakeholme Lock just south of Wansford on the Driffield Navigation (canal), and has been recorded at the monitoring station on the West Beck section of the river, indicating high Spring tides have regularly passed over Hempholme Weir. Increased operational use of the TSB may have limited, but not entirely removed, this incursion.

The River Hull's main tributaries are West Beck, Kelk Beck, Old Howe, Frodingham Beck, Driffield Beck, Skerne Beck, Nafferton Beck, Scurf Dike, Mickley Dike, Watton Beck and Catchwater Drain/Arram Beck. Together with the River Hull, these form the River Hull “high level system”. The numerous drains in the low lying land predominantly to the west of River Hull, including Beverley and Barmston Drain form the River Hull “low level” system.

Holderness Drain is no longer a tributary of the River Hull but is an important part of the drainage network in this area as it discharges flows from areas to the east of the River Hull directly into the Humber estuary. Similar to the River Hull, Holderness Drain comprises a high level and a low level system. Monk Dike, Catchwater Drain, Bowlams Dike and the lower part of Holderness Drain form the high level system. The numerous
drains in the low lying land to the east of River Hull, including the upper and middle parts of Holderness Drain form the Holderness Drain low level system. The embankments on the Holderness Drain high level system are much lower than those on the River Hull high level system, typically 1 or 2 m high compared to 4 m high.

3.1.14 The complexity of the drainage systems is due to more than 500 years of engineering modification. The response of the catchment to rainfall is also manifold because of the interaction of ground and surface water as well as the significant tidal influence of the Humber Estuary.

3.1.15 Most of the land adjacent to the river is low lying, including around 95% of Hull and significant parts of the East Riding. The city and surrounding rural areas would suffer from frequent flooding without the presence of both tidal and fluvial defences. This low-lying area is typically at risk from surface water, groundwater, fluvial (river) and tidal flooding, although in the north of the catchment the risk is just from fluvial flooding. Coastal and tidal flooding directly from the Humber, is considered as part of the Humber Flood Risk Management Strategy, which is currently under review.

3.1.16 A map of the key components of the study area is shown in Figure 10.

- River Hull Tidal Surge Barrier (TSB), at the mouth of the River Hull is designed to prevent flooding inland due to tidal surge
- There are a number of sluice structures installed which prevent reverse flow up the channels, for example at High Flags
- There are a number of pumping stations in the study area notably at Wilholme, Waterside and Hempholme, Tickton, Great Culvert and East Hull. Significant recent improvements have been made to East Hull Pumping station by Yorkshire Water.
3.2

3.2.1

This section outlines the main strategic features of the natural and human environment within the River Hull catchment.

3.2.2

A high level search of key environmental designations has been undertaken for the study area making use of the ‘MAGIC’ online database. The MAGIC database contains information relating to the natural environment with contributions from Defra, Heritage England, Natural England, the Environment Agency and the Marine Management Organisation.

3.2.3

The administrative areas of North Yorkshire, East Riding and Hull are rich in both cultural and natural heritage features. These features constitute a significant environmental resource, their value recognised by the extensive number of designated sites. In addition there are likely to be a significant number of locally designated or as yet undiscovered features (particularly archaeological) that will further extend the environmental resource and hence constitute a constraint and an opportunity.
People and property

3.2.4 The main centre of population is the urban area of Kingston-Upon-Hull where approximately 256,000 people live in the city, in 112,500 households (2011 census). The area is a major focus for jobs, commercial interests, services and facilities, and has diversified into smaller industries to replace the loss of the fishing industry. Renewable energy (wind turbine manufacturing) is set to become a significant new sector. High profile industrial and residential areas are also being developed to attract people to the city. Most of the city lies in the indicative floodplain.

3.2.5 The main East Riding of Yorkshire Council settlements within the study area are Beverley 30,500, the Haltemprice settlements of Anlaby, Willerby and Kirk Ella 23,000, Cottingham 17,500 and Driffield 13,000.

Land use and landscape

3.2.6 Land form in the study area is generally low-lying, which creates a broad and shallow river valley that is only perceptible on a local scale. The flat landscape offers few natural barriers to the flow of flood water on the floodplain. Trees and hedgerows are generally sparse, as agricultural improvement has led to the loss of most areas of semi-natural vegetation. There are smaller areas of pasture and parkland towards the towns of Beverley and Driffield. Greater coverage of vegetation is found to the north of the catchment, with plantations on the lower slopes of the Yorkshire Wolds.

3.2.7 Much of the study area is in agricultural use; the Agricultural Land Classification of the land is mostly grade 2 (very good, 55%) and grade 3 (moderate, 42%), with small areas of grade 4 (poor, 3%) and non-agricultural land. Most of the holdings are large-scale, mixed arable cultivations with some intensive livestock farming.

3.2.8 Hull is a major urban area, with industrial, commercial and residential land use. Based on historical land uses, it has the largest concentration of derelict and potentially contaminated land in the strategy area.

3.2.9 In addition, the study area benefits from a number of studies that categorise and evaluate the value of the landscape. These include the ongoing Historic Landscape Characterisation Study within Hull and the East Riding of Yorkshire sponsored by English Heritage, together with relevant landscape assessments e.g. the East Riding of Yorkshire Landscape Character Assessment (ERYC 2005).

3.2.10 There are no protected landscapes (e.g. AONBs, National Parks or Heritage Coasts) within the study area or are likely to be affected by the strategy.

Recreation and amenity

3.2.11 There are various sites that are important for formal and informal recreation and tourism in the study area, for example nature reserves such as Tophill Low, and disused gravel pits where sailing and fishing now takes place. Recreational activities along the River Hull include walking, bird watching, boating and fishing.

3.2.12 There is a network of public footpaths including the regional Trans-Pennine Trail. To the south of the study area, a green network of footpaths and cycle ways link the settlements in this area. The River Hull is navigable for leisure craft from Hull to beyond Beverley, along spurs to Corps Landing, Brigham and North Frodingham (freight can only go as far as Beverley). The Driffield Navigation Trust has been undertaking various restoration works to locks on the Driffield Canal for recreational usage.
Material assets

3.2.13 There are a number of transport routes in the study area, linking the urban centre of Hull and other settlements, and linking these to urban areas outside of the study area:

a) The main east-west route is the A63 (T), and this forms the boundary between the River Hull FRM Strategy and the Humber Estuary FRM Strategy study areas. The A63 (T) and the A1033 link Hull with Manchester and Leeds via the M62. North-south connections are provided by the A1079, A165, A1035, A164 and A15.

b) A rail link connects Driffield and Beverley to Hull.

c) The River Hull is navigable for freight barges through Hull, as far as Beverley, with wharf facilities along the river in Hull and Beverley. The river connects to the busy commercial waterway of the Humber Estuary, and this provides access to the international ports of Hull (and others around the estuary), which are of prime importance to the regional and national economy.

Natural environment

3.2.14 The whole of the Humber Estuary, which abuts the southern boundary of the study area, is internationally and nationally designated for its nature conservation importance (Site of Community Importance (SCI); Special Protection Area (SPA); Ramsar site; and Site of Special Scientific Interest, (SSSI)). It has been designated as it is one of the largest and most sediment laden estuaries, which gives rise to a wide range of habitats (e.g. sand dunes, salt marshes, sandbanks, shingle, and lagoons). This makes the estuary attractive to mammals such as grey seals and particularly to very large numbers of wild birds, especially those over-wintering. Allowance was made for a Habitat Regulations Assessment to be undertaken should the SEA show potential for RHICS proposals to harm these designations. Consequently an HRA has been carried out.

3.2.15 There are no National Nature Reserves within the study area. There are 15 SSSIs. Of these, four are in or immediately adjacent to the River Hull corridor:

1. The River Hull Headwaters are designated as the most northerly chalk stream system in Britain, and include adjacent remnants of ecologically important habitats, such as riverside wet grassland, woodland and fen.

2. Tophill Low consists of two artificial storage reservoirs 10 km south west of Driffield. The site is one of few inland standing open water bodies in the sub-region suitable for wintering wildfowl. Its grass banks attract a variety of butterflies and provide habitat for some scarce plant species. The North Marsh at Tophill has seen otters, water voles and the scarce water shrew, as well as a variety of dragonflies and damselflies.

3. Pulfin Bog is 16.8 ha of the last remnants of a spring-fed fenland reed swamp community in the Hull Valley, with botanical and ornithological interest.

4. Leven Canal is a 5km length of canal which cuts across marshland and meres of the Hull Valley, and following drainage of the surrounding land, is now a refuge for wetland plants. The water is fed by calcareous springs and is of very high quality.

3.2.16 As well as SSSIs, there are other areas within the catchment designated for nature conservation:

1. Otter and water vole – the Environment Agency is the lead partner for otter and water vole UK BAP species plans, and for the chalk rivers habitat plan.
2. Great crested newt

3.2.17 Within the catchment, other areas which are not as close to the River Hull are recognised as areas of conservation. Brandesburton and Frodingham ponds are considered one of the most important sites for wildlife in the valley. Additionally Driffield Canal provides habitat to birds, butterfly, water vole, weasel, stoat and otters.

3.2.18 Locally designated Nature Reserves are located in east Hull (Rockford Fields and Noddle Hill) and to the south of Beverley (Beverley Parks).

Fisheries

3.2.19 The River Hull Headwaters are recognised as a valuable salmon and fly fishery, with the main species in these upper reaches being brown trout, grayling and pike.

3.2.20 A good coarse fishery is supported in the middle and lower reaches of the Hull, which are more embanked and canalised with some saline influence, and in the agricultural drains and ditches where flows are slower. Species include perch, roach, gudgeon, dace, chub, bream and occasional flounder upstream of the confluence with the Humber. Good concentrations of fish are found associated with reedbed margins, vessels and areas of sluggish flow.

3.2.21 Eels are found throughout the system but in common with most of Europe, populations are believed to be a small fraction of their historic levels. On 15 January 2010, the Eels (England and Wales) Regulations 2009 came into force. These regulations afford new powers to the Environment Agency to implement measures for the recovery of European eel stocks. River lamprey are known to breed in the upper river and have been trapped along its length; therefore they have been scoped into the HRA. Consequently the SEA for this strategy highlights the need to consider eel and lamprey passes etc. in any structures that may be proposed, and limiting the timing of works to minimize potential harm, and other measures to support a healthy coarse fishery.

Cultural heritage

3.2.22 There is a wide distribution of archaeological and historic sites, buildings and remains throughout the Hull valley. There are a number of Scheduled Monuments distributed across the study area, 16 of which are within 1 km of the River Hull. A concentration of Scheduled Monuments are to be found in and around Beverley; however, individual sites are designated throughout the study area. There are no World Heritage Sites in the study area.

3.2.23 Within the study area there are 1296 Listed Buildings. Of these, 36 are Grade I, 77 Grade II*, 1171 Grade II. Listed Buildings are concentrated in Hull, Beverley and Driffield, with smaller clusters associated with Conservation Areas in Nafferton, Lockington, Bishop Burton, and Walkington.

3.2.24 Many of the existing settlements, for example Beverley (once England’s 10th largest and most important provincial town), are Medieval in origin, and there are several settlements that failed and became deserted. These are mainly located in the headwaters but also extend as far south as Eske near Beverley.

3.2.25 There are five Registered Parks and Gardens of Historic Interest wholly or partly in the study area, as listed below:

- East Park, Hull – Grade II; registered April 2001; 48.64 ha
- Pearson Park, Hull – Grade II; registered April 2001; 9.41 ha
• Risby Hall – Grade II; registered March 1999; 33.31 ha
• Dalton Hall – Grade II*; registered May 1984; 220.18 ha
• Sledmere House – Grade I; registered May 1984; 300.24 ha.

3.2.26 The Conservation Areas wholly or partly within the study area are:

• Hull City – contains 26 Conservation Areas, covering 6% of the city, two of which, Charterhouse and Old Town, are in the immediate vicinity of the River Hull corridor
• 42 of the East Riding’s 105 Conservation Areas are located within the strategy area.

3.2.27 The text above refers only to known, well documented and designated assets. Academic studies on the River Hull valley highlight the relative lack of designated heritage assets, bearing in mind the 8,000+ year history of settlement and migration patterns. There is an Area of Archaeological Importance identified in the saved Hull Local Plan. There is also known to be a high density of heritage features and archaeological remains within the Hull valley, many of which are unusually well preserved. There is growing evidence of the wealth of Mesolithic and Iron Age, Romano-British and Anglo-Saxon archaeology within the valley. Much of this lies just below ground and is prone to damage without care. Therefore, there are likely to be other historic environment assets that are, or could be, considered significant that have yet to be found. A careful watch will, therefore, be needed during preparation phases of projects, and during their construction on site.

Water

3.2.28 There has been a long history of modifying rivers and streams within the study area mainly to improve drainage. The study area now is predominantly a network of artificial channels contained within embankments, often above the surrounding land (dykes), and low lying drainage channels (ditches). Only sections of rivers and streams on the higher ground are in largely natural channels.

3.2.29 The higher ground to the north and west is mainly chalk which has a major influence on water in the catchment. Rain easily soaks into the ground through thin overburden where it remains as groundwater. Where the level of groundwater is higher than the surrounding land it emerges as springs which feed the headwater streams (known locally as kelds) and the main river. Water levels in these kelds are generally steady and rarely rise or fall quickly after rain. Most of the low lying ground is formed of poorly draining soils overlying the chalk and rain water mainly remains on the surface until it reaches the network of drains.

3.2.30 Water from the kelds is usually very high quality, but as the rivers and watercourses flow to the sea water quality is influenced by agricultural processes, discharges from sewage works, businesses, surface run off from highways and finally, tidal waters.

3.2.31 Under the Water Framework Directive, the Environment Agency published River Basin Management Plans for the whole of England and Wales in December 2009; it is due for review in 2015. The River Hull forms part of the Humber River Basin District. Of the 40 water bodies (lengths of river, drain, or canal) in the Strategy study area, the majority

6 Wetland heritage of the Hull Valley: an archaeological survey, by Robert van de Noort and Stephen Ellis (Humber Wetlands Project, University of Hull, 2000)
are classified as artificial or heavily modified. Less than a fifth of watercourses were assessed to be in good ecological status; the majority were classed as moderate, with two poor or bad. There are a variety of reasons for this, but the man-made or heavily modified nature of most water courses, their low or slow flow characteristics, enrichment by nitrates and phosphates and high sediment load all play their part. Appendix C of the SEA addresses WFD requirements, which will need to be developed in detail at project level as hydromorphology and ecological quality elements are likely to be affected.

3.3 Other relevant plans and strategies

3.3.1 This section examines other plans and strategies that are relevant to the strategy.

Local Authorities

3.3.2 As unitary authorities, the East Riding of Yorkshire and Hull City Councils have produced, or are producing, plans which relate to their functions as Lead Local Flood Authorities and Local Planning Authorities. As well as the Local Flood Risk Management Strategies referred to in Section 2 above, both have produced or are producing:

- Strategic Flood Risk Assessments (SFRAs) are local planning policy documents that inform decisions on planning applications and land use allocations. Hull City Council also produced a Surface Water Management Plan as an adjunct to its SFRA. (National Planning Policy Framework, Town and Country Planning Act 1990)
- Preliminary flood risk assessments – these give an assessment of historic and likely flood risk from surface and ground waters (2009 Flood Risk Regulations)
- Local Plans, which will set out land use allocations and spatial policies that will influence decisions on plans and projects (Localism Act 2011).

Yorkshire Water plans

3.3.3 Following the 2007 floods, Yorkshire Water invested approximately £40 million at the West Hull, East Hull and Bransholme Pumping Stations to increase their resilience under similar extreme weather events. The company is currently investing a further £16m at Bransholme PS to increase its capacity as the Kingswood and Bransholme catchment develops.

3.3.4 It also commissioned a study by Arup to investigate future requirements for the wider urban drainage system serving the Hull and Haltemprice sub-catchment. This indicates that to increase protection to a 1 in 75 year standard a future long term investment of £362m is required, £183m of which is required from water company regulated budgets and another £179m from other RMAs. This strategy recognises that significant additional work will be required by partners working with YW to develop options in more detail during the company’s next five year (Asset Management Programme 6 (AMP6)) investment period, with a view including potential projects in its AMP7 and other partners’ programmes from 2020. YW has allocated significant additional funding to be able to develop the Arup study.

3.3.5 The ERYC Local Flood Risk Management Strategy sets out objectives and measures that water companies/OFWAT must have regard to when deciding on their methodology for price determination. The objective sets out that OFWAT should seek direct consultation from LLFAs in respect to flood risk priorities for the next investment period.
Local Economic Partnership plans

3.3.6 The catchment area is covered by two LEPs – one for the Humber and one for North Yorkshire, York and the East Riding (NYYER). Both have produced Strategic Economic Plans (SEPs) that refer to flood risk. The Humber LEP has identified flood risk management as a strategic enabler and a sector of strategic importance. It seeks to stimulate economic development through further investment in flood and coastal risk management and contains objectives which make direct reference to supporting RHICS and the provision of defences to deal with surface and river flooding risk within the River Hull catchment. Significantly, through its Investment and Delivery Plan it has indicatively agreed to make a contribution of £12m towards the projects identified in this strategy.

3.3.7 In the NYY&ER LEP’s strategic plan recognises that parts of the East Riding in particular are at significant flood risk. Flood mitigation is needed to enable development opportunities, and ‘Action 19’ seeks to target flood prevention measures. In terms of opportunities, biorenewables and low carbon energy are two of its sectors it is seeking to enhance. In particular, opportunities arise at the farm level to support the under-resourced biorenewables supply chain and to provide on-farm low carbon microgeneration.

3.3.8 Specific linkages to both LEPs’ SEPs are also included at the final options analysis stage of the strategy.

Hull and Coastal streams Catchment Flood Management Plan (CFMP)

3.3.9 The Hull and Coastal Streams CFMP is a high-level strategy that sets out the Environment Agency’s policies for the long-term management of flood risk in the whole of the River Hull catchment. It also included rivers and streams that drain to the Humber between the Wolds and the River Derwent, land drainage in south Holderness, coastal streams and drains in north Holderness, and the Gypsey Race from the high Wolds to Bridlington. It was signed off by the EA in 2010.

3.3.10 The CFMP divided the Hull catchment into upper and lower sections with differing policy outcomes. The recommended policy approaches were:

“For the Upper Hull (north of the City boundary), under policy Option 3, the short term (up to five years) vision for the policy unit is that we will continue to provide flood protection across the area. In the medium term we anticipate difficulties in continuing to get flood risk funding for all of our current activities. We will continue to develop a more detailed understanding of flood risk from the implementation of the River Hull Flood Risk Management Strategy and partnership working. This CFMP policy will be kept under review and may be changed as a result of this partnership working”.

3.3.11 The CFMP’s proposed actions for the Upper Hull are to:

a) Finalise, publish and implement the River Hull flood risk management strategy and continue consultation with stakeholders during the implementation of its actions and work in partnership to secure the long-term future of the flood risk assets

b) Produce and implement a System Asset Management Plan to determine the most sustainable approach to managing assets
c) Consider the implications of changing the flood regime on SSSIs. The findings should be used to inform future sustainable approaches to flood risk management and ensure that the condition of each SSSI is maintained, and where possible improved.

3.3.12 For the lower Hull catchment (Hull and Haltemprice) the CFMP’s policy approach was:

“Through Policy Option 5, our vision is for flood risk management to be improved for all sources of flooding. Partnership working between professional partners involved in managing risk will continue, in order to better understand the complexity of the flooding mechanisms and find suitable sustainable solutions. This should achieve an improved standard of protection within the Lower Hull. This protection will be focused on surface water risk, as well as some river flooding risk”.

3.3.13 The proposed actions for the Lower Hull were to:

a) Work in partnership to develop and implement feasibility studies for schemes to manage flood risk. This includes the long term maintenance and refurbishment of the Hull TSB
b) Work with Hull City Council and landowners, make improvements were required to flood defences on the River Hull
c) Work to improve the flood forecasting system for the area, and improve the flood warning
d) Service available
e) Ensure emergency response plans are reviewed and take account of increases in flood
f) Risk through climate change and other catchment changes
g) Implement the Surface Water Management Plan and Aqua Green Projects within Hull
h) Improve public awareness of the risk of flooding from all sources
i) Implement the River Hull flood risk management strategy and continue to consult with stakeholders during the implementation of its actions.

Flood Risk Management Plans

3.3.14 In order to meet statutory requirements both the EA and LAs in the study area must produce Flood Risk Management Plans. An FRMP is an evidence based report and a strategic planning tool. It identifies flood risk in a given area and sets out objectives and measures to reduce and manage the risk whilst at the same time considering wider social, economic and environmental factors in the study area.

3.3.15 It is acknowledged that the most significant flood risk in the Hull catchment is from the tidal Humber. Without the defences to the Humber frontage some 5,500 hectares of land and 131,000 properties would flood. However, the Humber has its own 2008 flood risk management strategy, which is currently undergoing a review. Care has been taken in the preparation of RHICS not to claim benefits that would arise from actions proposed via the Humber’s FRMS. At the time of writing a revised methodology is being prepared to help determine how benefits should be apportioned across the Humber and for the flood risk management strategies of the other rivers that flow into it, to ensure there is no double counting and that no scheme is undermined when funding is sought.

3.3.16 RHICS has considered the interaction of tidal influences on fluvial flows and the capacity of the river to accommodate two water sources simultaneously, and how this impacts
on flooding and flood risk. Several options for managing this have been modelled and assessed (see section 9).

3.3.17 The EA FRMP that covers the study area contains generic objectives and measures at the Humber Basin Scale (one fifth of England) and catchment specific objectives and measures for the River Hull. The EA must produce these plans when considering flood risk from Rivers, Sea and Reservoirs.

3.3.18 ERYC and HCC as Lead Local Flood Authorities must also produce a FRMP in respect of Surface and Groundwater risk in the Hull and Haltemprice Catchment. This is because this catchment area is one of 10 in England that has a risk above a national reporting threshold. EYRC has produced an independent ERYC FRMP for this catchment, this plan was adopted by the council on 18th November 2015 and is available on the ERYC website. The HCC has decided to contribute information to the draft EA Humber River Basin District FRMP, this plan is expected to be published Spring 2016.

Other flood risk management projects

3.3.19 Following the June 2007 flood event, a number of studies have been identified and promoted by the various flood risk agencies. It was recognised that there needed to be a multi-agency approach as the risks being addressed can in some cases, cross over a number of areas of responsibility. Many of these studies are now moving through to design and planning stages, having secured funding.

3.3.20 The Environment Agency has completed a £10million refurbishment of the River Hull Tidal Surge Barrier (TSB) and is promoting a scheme to investigate options for pumping flows from the Holderness Drain at times when it becomes tide-locked by the River Humber. The scheme included options for flood plain storage and replacing/upgrading pumping equipment at East Hull PS, but recognising it is integral to the scope of the RHICS study, the scheme is currently on hold pending the outcome and recommendations of the RHICS study.

3.3.21 Parts of west and north of Hull, and the adjacent East Riding suburbs, are identified as having significant surface water flooding risks. These are being investigated by East Riding of Yorkshire Council working closely with Hull City Council, Yorkshire Water and the Environment Agency. Flood Alleviation Schemes (FAS) are being developed in the Willerby and Derringham areas (WaDFAS), Cottingham and Orchard Park (COPFAS), Anlaby and East Ella (AEEFAS) and Hull and Holderness Flood Alleviation Scheme (HHFAS). WADFAS is now considered operational, substantial completion is expected Summer 2016. COPFAS is in development stage with construction expected to start on site 2016-17. AEEFAS phase 1 is on site for preparatory demolitions with phase 2 is expected on site 2017-18 and HHFAS phase 1 tidal works are on site and phase 2 inland works set to start 2017-18. Up to date information on all these schemes is available on ERYCs flood risk website.

3.3.22 The City Council is working with Yorkshire Water to tackle local surface water flooding ‘hotspots’ and has run successful local events to better understand community concerns and develop local solutions.

3.3.23 Within other parts of the catchment East Riding of Yorkshire Council is developing a programme of other local flood alleviation schemes and local highway drainage improvement schemes.

Planning and development
The national spatial planning system has changed significantly since the publication of the River Hull Flood Risk Management Strategy in 2010. The Localism Act of 2011 replaces the requirement for Local Planning Authorities (LPAs) to produce Local Development Frameworks with the requirement to produce Local Plans. Regional Spatial Strategies are now revoked. Until LPAs produce their Local Plans, predecessor plans are saved, and form the basis for decision making on planning applications. This includes the Joint Structure Plan, the East Riding’s four Local Plans (based on the former Borough Council areas), and Hull’s CityPlan Local Plan.

The National Planning Policy Framework (see below) indicates that appropriate weight can be given to emerging plans or work already in preparation (such as studies and draft policies prepared for the Local Development Frameworks), as long as certain conditions are met.

The Localism Act also places a duty on LPAs to co-operate, and the emerging Local Plans for the East Riding and Hull reflect this. The Councils have agreed a Joint Planning Statement (2014), which sets out their joint priorities for spatial planning. Both Local authorities are committed to the regeneration and transformation of Hull; realising the potential of the Humber Ports alongside the growth of the renewable and low carbon energy sector; and protecting the integrity of the internationally important environmental and biodiversity designations around the Humber Estuary. The 2005 Joint Structure Plan is a saved plan, and the authorities are producing joint Waste and Minerals Local Plans.

The East Riding’s Local Plan Submission Strategy Document (April 2014) deals with flood risk through policies on climate change and the environment. This includes measures to:

a) Conserve, enhance and link green infrastructure networks to provide flood management, shading for urban areas and natural air conditioning
b) Promote development away from areas of high flood risk, as far as possible
c) Limit run-off rates
d) Ensure development does not increase flood risk on the development site or elsewhere
e) Ensure developments incorporate SUDs where possible
f) Limit culverting
g) Ensure development is safe from residual risks such as ensuring resilient and resistant design and ensuring that there is access to a safe place during times of flood, and
h) Support sustainable flood management proposals.

Hull’s Local Plan Issues and Options consultation document (June 2014) specifically addresses flood risk in a separate Section. There are links to it in the Climate Change, Open Space and Natural Environment Sections. It asks the following questions:

a) Should the Local Plan include a policy about sustainable drainage solutions?
b) Should the proposals map identify important flood defences?
c) Should there be policies to protect and enhance these defences?
d) Do you agree with the Council using its own locally agreed approach to flood zones when applying the sequential test?
e) Do you agree that the development of the functional flood plain should be restricted when considering potential land uses?
f) Do you agree that the locally determined Standing Advice should be used when requiring information and determining planning applications
3.3.29 The two LPAs have also produced Strategic Flood Risk Assessments (SFRAs) in accordance with Planning Policy Statement 25 on Flood Risk; they liaised to ensure compatibility of the results. The SFRAs define different zones of flood risk. The policy response in both draft Local Plans is to steer development towards areas with the least risk of flooding. As an adjunct to its SFRA, Hull City Council also produced a Surface Water Management Plan (SWMP) with key partners in 2009.

3.3.30 The purpose of the SWMP is to:

a) To provide a properly conceived prioritised long-term strategy for the City of Hull’s surface water management
b) To provide a strategic overview of surface water flood risk across Hull City with detailed assessment of surface water risk at high risk locations, including identification and assessment of options and selection of preferred options for implementation
c) To consider the use of Aqua Greens (dual use public recreation and potential surface water temporary storage areas) alongside other surface water drainage options
d) To consider other plans and initiatives in the City of Hull in order to produce a shortlist of surface water drainage options that are effective, achievable and cost beneficial to the management of surface water flooding in the city
e) To provide on the ground improvements to surface water flood risk reduction as soon as possible.

3.3.31 Both Authorities Local Transport Plans recognise the impact of climate change on the integrity of highway assets.

Environment

3.3.32 There are many strategies and plans, both national and local, which consider environmental issues. There are both opportunities and constraints in linking these plans with flood risk management.

3.3.33 The key strategic issues and opportunities identified for the Strategy study area are listed below, and these are the issues that have shaped the Strategic Environmental Assessment update:

a) Safeguard the health, security and well-being of the population, and reduce the economic and social cost of flooding
b) Protecting properties and material assets in the floodplain
c) The proximity of Humber Estuary, which is of international importance for nature conservation (addressed primarily in the Habitat Regulations Assessment)
d) Protecting Sites of Special Scientific Interest (SSSI) located close to the River Hull, and the opportunity to improve their condition
e) Potential impacts on protected species and the river’s coarse fishery, and what opportunities exist to create new, replacement or improved habitats, particularly wetlands, woodlands or green corridors
f) Protection of good quality agricultural land to help maintain food security and farm incomes
g) Taking the opportunity to improve brownfield sites and unlock land constrained by flood risk and widen economic opportunity by reconnecting communities to their river

h) Protecting scheduled monuments, listed buildings, conservation areas, parks and other designated and non-designated heritage assets in the study area; helping secure as yet undiscovered heritage assets

i) Supporting the development of recreation and amenity facilities in the study area such as opportunities for better access to the riverside with footpaths and cycle ways, opportunities to create recreational corridors that link in to national networks

j) Maintaining and improving water quality, and minimising pollution.

3.3.34 The following strategies and plans are relevant to the key strategic issues, where there might be opportunities or constraints.

3.3.35 UK Biodiversity Action Plan (BAP), Hull Local BAP and East Riding Local BAP:

The UK BAP is the UK’s initiative to maintain and enhance biodiversity (the variety of flora and fauna). BAPs are also prepared at a local level. There could be opportunities associated with UK / local BAP habitats and species through the delivery of the RHICS, or constraints where the Strategy may not assist with BAP targets. However, these opportunities or constraints have not been considered at the Strategy level, and would need to be considered as part of project level Environmental Impact Assessment (EIA).

3.3.36 Humber Eel Management Plan:

Any improvements to habitats and water quality, and the naturalness of the river system are likely to contribute positively to the Eel Management Plan. There is a potential constraint for the RHICS to hinder the Humber Eel Management Plan if migration of eel is in any way inhibited. The provision of eel passes at sluices and obstructions and screens at pumping stations will need to be considered either as stand-alone measures or when implementing strategy components.

3.3.37 Pulfin Bog Water Level Management Plan (WLMP):

The EA has agreed with NE that a Water Level Management Plan is not currently required as Pulfin Bog is currently in ‘favourable’ condition. There is the potential for negative effects, directly or indirectly, for a number of the Strategy elements being considered. Long-term increased flooding of the SSSI has the potential to have a negative effect on the habitat types present. The final package of proposals should ensure no negative effects. Further detailed work is needed with Natural England, to consider this. Project costings have allowed for mitigation.

3.3.38 River Hull Headwaters Restoration project:

A partnership management plan has been produced for the River Hull Headwaters SSSI – Restoring the River Hull Headwaters – River Restoration Plan, 2010. It includes measures for managing water levels, so no formal water level management plan is being produced. There are synergies that can be explored between this Strategy and the RHHW Strategy and RHICS has the potential to contribute, to some degree, to the objectives of the Restoration Plan.
Before options can be designed for managing flood risk, it is important to understand the meaning of flood risk and how it can be categorised within the catchment and who is responsible for management. This section aims to address all of these points, as well as highlighting significant flood events that have occurred within the basin in recent years.

### 4.1 Definitions

4.1.1 As with all risk analyses, there are two elements that need to be considered, namely probability and consequence.

4.1.2 What is the probability that a flood event with a specified water level will occur?

This is usually referred to as a ‘return period’ and can be expressed as, for example, a ‘1 in 100 year event’. This example refers to the expected probability that an event occurring in any given year, in this case a 1% probability of the event occurring again within the year. The term AEP is used – Annual Exceedance Probability.

4.1.3 What are the consequences of the flooding and what damage will result?

This is based on the damage or negative affect that will occur should a flood occur, these are measured by receptors, the case of FDGiA funding these are mainly residential properties. Other funders may consider the negative affect on business costs to be more important.

### 4.2 Causes of flooding

4.2.1 The study area is influenced by four types of flooding; surface water, fluvial (river), groundwater and tidal.

4.2.2 In recent years a number of significant flooding events have occurred within the study area, these are described below:

A) Fluvial or River flooding

4.2.3 Floodwater has regularly overtopped defences in the upper reaches of the River Hull between Driffield and Hempholme Weir and on Frodingham Beck, Driffield Canal and Old Howe near Brigham and North Frodingham. Flooding occurs along some parts of Beverley and Barmston Drain and Holderness Drain relatively frequently.

B) Tidal flooding

4.2.4 On 5 December 2013 a storm surge moved around the UK coastline affecting coastal locations before moving down the East coast and into the Humber Estuary causing flooding in East Yorkshire. The highest ever tide was recorded at the River Hull TSB which provides a 1 in 200 year standard of protection.

4.2.5 The surge coincided with high spring tides, resulting in record water levels along the coast and tidal rivers, causing flooding to more than 400 properties in Hull and the East Riding, significant areas of agricultural land (estimated at 6000 acres or 2400ha) and caravan sites particularly along the coast were also affected.
4.2.6 The event exceeded previous tide levels in Hull, with a record level of 5.8m AOD, only 500mm below the top of the TSB. Infrastructure including roads, railways, power supply and sewerage services were also affected. Many roads were closed during the event and some remained closed for several days as flood waters trapped behind defences slowly subsided.

C) Groundwater flooding

4.2.7 Groundwater flooding occurred in areas to the west of the River Hull along the edge of the Wolds where the water table in the chalk aquifer is close to the ground level and where natural springs can occur (Figure 11).

4.2.8 2012 was the second wettest year on record in England and 2014 the fourth wettest, resulting in significant property flooding at Kellythorpe (Driffield). A study is to be carried out to look at mitigation measures.

Figure 11 - Location of natural springs
recorded incident of any type of flooding: by property numbers) occurred on the 25 June 2007 when over 14,000 properties were flooded internally, principally due to surface water run-off, especially in the Hull and Haltemprice Catchment.

4.2.10 This event resulted in hundreds of millions of pounds of damage with over 35,000 people displaced from their homes. This was the first of two events that year that resulted in the Pitt Review of 2008 leading to significant changes in primary legislation.

4.2.11 There have been a number of subsequent surface water flooding events in the study area since 2007, notably a series of flash floods during the summer of 2014 affecting Beverley, Cottingham, Anlaby Common, Anlaby Park and East Ella. Table 6 below summarises these events.

Table 6 - Recorded flood events in the catchment

<table>
<thead>
<tr>
<th>Date</th>
<th>Details</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953, 31 January</td>
<td>A major depression over the northern North Sea caused a storm surge that affected large parts of the east coast, leading to the breaching and overtopping. Flooding in Hull City Centre.</td>
<td></td>
</tr>
<tr>
<td>2000, 4 November</td>
<td>The wettest autumn since 1766 caused flooding of smaller land drains in Haltemprice, west Hull and south Holderness. Flooding to Beverley and Barmston and Holderness drains (main rivers). Widespread flooding of farmland around Frodingham.</td>
<td></td>
</tr>
<tr>
<td>2006, 27 July</td>
<td>Flash floods in East Yorkshire after heavy downpours and hail storms. Flooding in Main Street, Willerby 2ft deep.</td>
<td></td>
</tr>
<tr>
<td>2007, June – July</td>
<td>Major surface water flooding following second intensive rainfall event that month (15th June). Up to 125mm rainfall in one day. Widespread flooding from various sources in Hull and East Yorkshire, Multiple events cause flooding to thousands of properties. High volume pumps deployed to pump water from Hull streets. Water waste deep in some parts of the city. Over 12000 flooded properties in the study area.</td>
<td></td>
</tr>
<tr>
<td>2012, 25 August</td>
<td>Heavy rainfall and hailstones caused widespread highway flooding on the 25th August. 21 properties (19 residential and 2 commercial) were flooded as a result of the intense storms causing capacity exceedance of the highway drainage system.</td>
<td></td>
</tr>
<tr>
<td>2013, December</td>
<td>Largest tidal surge experienced for 60 years and highest tide recorded at the Hull Tidal Surge Barrier. The surge coincided with high spring tides causing flooding to more than 400 properties in the East Riding and Hull. Ingress of flood waters occurred into the English Street area and flows spread into the city centre as far as Hessle Road. Flood damage was recorded at 115 businesses and 149 residential properties.</td>
<td></td>
</tr>
<tr>
<td>2014, 7 July</td>
<td>Heavy summer rainfall caused localised flooding in Cottingham. Various other locations affected by summer storms such as Beverley, Anlaby and East Ella. Intense rainstorm overwhelmed the drainage network in Cottingham, causing damage to 107 residential and 12 commercial properties.</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 - RMAs in River Hull catchment

<table>
<thead>
<tr>
<th>Risk Management Authority</th>
<th>Name of Organisation</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment Agency</td>
<td>Environment Agency</td>
<td>Main river flooding and strategic oversight of all forms of flood risk at national level.</td>
</tr>
<tr>
<td>Lead Local Flood Authority</td>
<td>East Riding of Yorkshire / Hull City Councils</td>
<td>Lead authority for managing local flood risk. Land Drainage Authority. Highways.</td>
</tr>
<tr>
<td>Internal Drainage Board</td>
<td>Beverley and North Holderness Internal Drainage Board South Holderness IDB</td>
<td>Ordinary watercourses identified as main drains located in IDD.</td>
</tr>
<tr>
<td>Water Company</td>
<td>Yorkshire Water</td>
<td>Duty to ‘effectively sewer’ an area.</td>
</tr>
<tr>
<td>Highway Authority</td>
<td>Hull City Council East Riding of Yorkshire Council Highways Agency</td>
<td>Highway drainage including some bridges and culverts.</td>
</tr>
</tbody>
</table>
4.3 Flood management in the catchment

4.3.1 Flood risk management is the responsibility of everyone, not solely the organisations identified by the Flood and Water Management Act 2010. No single body has the means to reduce all flood risk. Effective management requires collaborative working between organisations with a range of relevant duties and powers. Regional Flood and Coastal Committees (RFCCs) play a fundamental role in the management of flood risk in this area.

Regional Flood and Coastal Committees

4.3.2 RFCCs are committees established by the Environment Agency under the Flood and Water Management Act 2010. The River Hull catchment is covered by the Yorkshire RFCC. They meet on a quarterly basis and bring together members appointed by Lead Local Flood Authorities (LLFA) and independent members with relevant experience for three purposes:

- To ensure there are coherent plans for identifying, communicating and managing flood and coastal erosion risks across catchments and shorelines;
- To promote efficient, targeted and risk based investment in flood and coastal erosion management that optimises value for money and benefits for local communities, and;
- To provide a link between the Environment Agency, LLFAs, other Risk Management Authorities (RMAs) and other relevant bodies to promote a mutual understanding of flood and coastal erosion risks in its area.

Environment Agency

4.3.3 The Environment Agency has a role in flood risk management, both as a national strategic body and also, more locally, operating as an RMA at a catchment and area level. Aspects of the strategic role that are relevant to the RHICS are:

a) The use of Catchment Flood Management Plans;
b) Collation and review of assessments, plans and maps that LLFAs produce to meet the Flood Risk Regulations;
c) Provision of data, information and tools to inform government policy and aids RMAs in delivering their responsibilities;
d) Supporting collaboration, knowledge building and sharing of good practice including capacity building;
e) Managing the RFCCs and supporting their decisions in allocating funding for flood defence and flood resilience schemes;
f) Monitoring activity and reporting on flood and coastal erosion risk management; and
g) Providing grants to RMAs to support the implementation of their incidental or environmental powers.

4.3.4 The Environment Agency’s local role as an RMA is relevant in the following areas:

a) Regulation of main rivers including an assessment of flood risk and permissive powers to require landowners to maintain rivers on their land / property where flood risk is a concern;
b) Regulation of large raised reservoirs including an assessment of flood risk;
c) Communication about risk and flood warnings to the public, the media and to partner organisations;
d) Supporting communities to be flood resilient through sharing best practice and provision of information advising on the planning process;

e) Emergency planning, and input to Multi Agency Flood Plans (MAFPs) are developed by local resilience forums; and

f) Bringing forward flood defence schemes through the RFCCs, working with the LLFAs and local communities to shape schemes which respond to local priorities.

**Lead Local Flood Authorities**

4.3.5 LLFAs are established at County or Unitary Authority level where flood risk is of concern. Hull City Council and East Riding are LLFAs. They are also SuDS Approval Bodies (SABs) for sustainable drainage solutions, and also have powers to establish governance arrangements for the delivery of flood risk management functions.

4.3.6 In addition, LLFAs have permissive powers which allow them to carry out practical works to manage flood risk from surface water and groundwater. Also, both councils have a number of other roles that relate to flood risk management, these include:

- **Highway Authority** – Management of public, non-trunk roads, minor roads and the associated highway drainage.

- **Planning Authority** – Both East Riding of Yorkshire Council and Hull City Council are Unitary Authorities. They have to prepare a local plan containing policies to guide development including minerals and waste in their respective administrative areas. The local plan is informed by a Strategic Flood Risk Assessment (SFRA) to ensure future development is steered to areas of lowest flood risk first;

  Both LLFAs are responsible for deciding whether a development (from minor to major development) should go ahead. The policies within the local plan form the basis of deciding planning applications alongside national planning policy;

- **Emergency Planning** – The authorities are category one responders under the Civil Contingencies Act (CCA) and the role is set out in the Multi Agency Flood Plan.

4.3.7 Proposals were published by Defra in March 2005 for a more holistic approach to flood management. Defra has promoted an integrated approach to drainage management in high-risk urban areas through encouraging LLFAs to produce Surface Water Management Plans. These cover flooding from fluvial, drainage, surface water and groundwater sources. This will enable the authorities responsible for different parts of the drainage system to work together to assess and manage flood risks, taking a long-term strategic approach. The City Council produced an SWMP in November 2009.

**Legal responsibilities for the River Hull**

4.3.8 Vessel and bankside structure ownership highlights the issue of who has or retains authority over berthing and consenting of structures. Within the city, Hull City Council is the navigation authority, giving it several powers (consolidated into the Kingston-Upon-Hull Act, 1984). The Act sets statutory flood defence levels on the River Hull through the city. It also gives Hull City Council powers to serve notices on the owners of land adjoining the River Hull requiring them to carry out works to prevent the overflow of the River Hull. If the landowner does not carry out the works the Council
has the power to do the works itself and recover its costs. The Act also gives the City powers to keep the channel clear and charge vessels that berth for over three months.

### 4.3.9 Between the city boundary and Hempholme weir and lock the River Hull is classed as a free navigation – there is no navigation authority. From Hempholme to Emmotland, close to where the Driffield Navigation (canal) starts, the Driffield Navigation Trust has powers. North of Emmotland the river again reverts to free navigation. Beverley Beck is within the ownership and control of East Riding of Yorkshire Council; it is also the Navigation Authority for this body of water.

### 4.3.10 As a main river, the Water Resources Act 1991 (s.109) and associated byelaws (currently the Yorkshire Land Drainage Byelaws 1980) gives the Environment Agency permissive powers to require consent for works in, over, under or adjacent to the entire River Hull and to take enforcement action where the flow of water in the channel of the river is restricted.

### Table 8 - River Hull flood defence assets

<table>
<thead>
<tr>
<th>Asset</th>
<th>Description</th>
<th>Amount (km) or Capacity (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main river channels</td>
<td>River Hull</td>
<td>50 km</td>
</tr>
<tr>
<td></td>
<td>Beverley and Barmston Drain</td>
<td>23 km</td>
</tr>
<tr>
<td></td>
<td>Holderness Drain</td>
<td>23 km</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>136 km</td>
</tr>
<tr>
<td>Flood banks/walls</td>
<td>River Hull</td>
<td>75 km</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>86 km</td>
</tr>
<tr>
<td>Main pumping stations</td>
<td>Hempholme</td>
<td>1.9 m³/s</td>
</tr>
<tr>
<td></td>
<td>Wilholme</td>
<td>8.5 m³/s</td>
</tr>
<tr>
<td></td>
<td>Tickton</td>
<td>2.5 m³/s</td>
</tr>
<tr>
<td></td>
<td>Great Culvert</td>
<td>12 m³/s</td>
</tr>
<tr>
<td></td>
<td>East Hull (EA)</td>
<td>7.5 m³/s</td>
</tr>
<tr>
<td>Outfall structures</td>
<td>Hedon road outfall</td>
<td>1 no</td>
</tr>
<tr>
<td></td>
<td>Holderness Drain: Pointing doors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mickley Dike</td>
<td>2 no</td>
</tr>
<tr>
<td></td>
<td>Watton Beck</td>
<td>2 no</td>
</tr>
<tr>
<td></td>
<td>Scurf Dike High Flags outfall,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Beverley and Barmston Drain: Pointing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>doors</td>
<td></td>
</tr>
<tr>
<td>Other Assets</td>
<td>Hull Tidal Surge Barrier</td>
<td></td>
</tr>
</tbody>
</table>

The Pitt Review, Interim Report, Cabinet Office (December 2007), 10km of the River Hull and 8km of other rivers are maintained by third parties

### Flood defences

#### 4.3.11 Throughout most of the course of the River Hull the surrounding land is at a lower elevation than the river. To protect the surrounding land, the river is flanked by high flood defences, mainly in the form of engineered earth embankments with some hard defences such as concrete walls and sheet piling.

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7 https://www.waterways.org.uk/waterways/waterways_hk
There are a number of pumping stations and other ancillary assets associated with the river system. The majority of these assets are inspected and if necessary maintained at the public expense by the EA.

**Assessment of current flood risk**

This strategy has examined flood risk in relation to return periods of between 20% AEP and 1% AEP, utilising a one-dimensional hydraulic model of the River Hull, Holderness Drain and their major tributaries coupled with a two-dimensional model of the floodplain. The predicted inundation extent and depths for current conditions for a 1% and 20% AEP event are shown at figure 12 below and detail maps are available in Annex A, all assuming current operational rules and functionality. These predictions relate to an extreme event in relation to fluvial action. Tidally-dominant extreme events have no predicted detriment provided the River Hull TSB operates in accordance with operational rules.

For a 20% AEP event, substantial (>0.5m) depths of inundation are predicted at the following locations:

a) At the confluence of the Crofts Drain with the Holderness Drain  
b) Beyond the southern bank of Bowlams Dike (a tributary of the Monk Dike)  
c) Within the Eske Wetland area, which is contained by high-flow embankments on the eastern edge of the wetland  
d) Largely agricultural land beyond the western bank of the Beverley & Barmston Drain, both north and south of Watton Beck  
e) Within the old course of the River Hull near Rotsea  
f) Between the Driffield Canal and River Hull near Brigham Ings  
g) Beyond the south bank of the Mickley Dike near King’s OXgang.

There is also a reasonable extent of low-depth inundation in the vicinity of Bransholme, as well as in Beverley, both of which are economically significant due to the potential for much higher flood damages in these urban areas relative to the agricultural area comprising much of the predicted inundation extent.
4.4.4 For a 1% AEP event, the extent of inundation increases in both Bransholme and Beverley, although peak depths are predicted to remain below 0.5 m. The depth and extent of inundation increases at all locations listed above, particularly in the Roam Drain above its confluence with the Mickley Dike, the floodplain north and south of Watton Beck, the Arram Carrs area, and around Dunswell. There is also a substantial amount of additional inundation from the Arnold and Riston Drain, to the east of Monk Dike, while the extent of flooding from the Holderness Drain north of Tickton is predicted to substantially increase relative to the 20% AEP event.

4.5 Flood risk in the future

4.5.1 Scientific evidence continues to demonstrate how global climate is changing. Sea levels are already rising and they are predicted to rise further due to thermal expansion of the oceans and melting glaciers and ice-caps. Climate change may also produce altered weather patterns. This could mean changes to the frequency, duration and severity of rain storms across the UK. Winters are predicted to be wetter and summers drier. An increased frequency of heavy, intense rainfall also seems likely, both in winter and in summer thunderstorms.

4.5.2 Current Defra estimates are that sea level rise will accelerate from 4mm/year at present to 15mm/year after 2085. The total sea level rise over the next 100 years is predicted to be approximately 1m. Defra recommends that increases in peak river
flows of 10% may be expected by 2025 and an increase of flows of 20% any time between 2026 and 2115 as a result of changing rainfall patterns.

4.5.3 Modelling conducted as part of the present study considered the potential impacts of increased peak river flows as well as increased River Humber tidal levels (resulting from sea level rise) associated with climate change upon increasing fluvial-dominant flood risk in the River Hull and Holderness Drain systems.

4.5.4 Based on the Defra estimates below, Table 9 details the parameterisation assumed for tidal and fluvial uplift for three future epochs, with model predictions obtained for each epoch in relation to the 1% AEP flood event. Each option has been modelled using these assumptions. The model also builds in forecasts for changes to rainfall amounts.

Table 9 - Parameterisation of climate change used in model assessment

<table>
<thead>
<tr>
<th>Epoch Label</th>
<th>2055</th>
<th>2085</th>
<th>2115</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td>2025-2055</td>
<td>2055-2085</td>
<td>2085-onwards</td>
</tr>
<tr>
<td>Fluvial uplift %</td>
<td>15</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Tidal uplift (mm)</td>
<td>235</td>
<td>535</td>
<td>925</td>
</tr>
</tbody>
</table>

4.5.5 Sea level rise associated with climate change directly impacts water levels within the tidally-impacted extent of the River Hull. Combined with increased flows, peak water levels associated with a given return period will rise due to climate change in this extent. However, the river embankments are generally high enough in this extent to contain higher peak water levels, with the majority of the predicted flood risk detriment due to climate change experienced in the areas adjoining the Beverley and Barmston Drain (partly due to the relative ineffectiveness of pumped transfers, but primarily due to increased backup in this drain combined with its lack of freeboard) and the upper catchment (particularly Mickley Dike, Roam Drain and the old course of the River Hull near Rotsea). On the assumption that the 4.25m AOD activation threshold of the River Hull TSB is not adjusted in response to climate change, sea level rise will also have the impact of increasing the frequency of activation (i.e. closure) of the barrier, with modelling suggesting that the TSB will begin to act as an important regulator against fluvial flood risk as well as tidally-induced flood risk (i.e. as the tidal barrier acts to reduce tidal intrusion from “typical” tides, and hence decrease the typical antecedent river water level prior to a given fluvial event). This intervention is known as Sluicing for Tidal Exclusion (SfTE).

4.5.6 In contrast, gravitational discharge from the Holderness Drain into the River Humber is controlled by a structure preventing backflow, with discharge supplemented via pumping during high water conditions in the River Humber so SfTE is already a permanent feature. The impact of sea level rise is to reduce the cumulative volume of gravitational drainage and increase the cumulative volume of pumping, such that the East Hull PS is shown by modelling to be increasingly critical for flood risk management when climate change impacts are considered. On the assumption that the pumps continue to operate at current capacity, increased flows have a much more substantial impact than sea level rise upon increasing flood risk to the Holderness Drain system due to climate change.
Relative to predicted flood inundation for a 1% AEP design event based on current climate conditions, the impact of climate change is forecast to increase the peak depth of flooding at all locations that are shown to inundate for current climate conditions. The spatial extent of flooding is also predicted to be marginally larger at all locations, with a significant increase in extent west of Leven (north and south of Leven Canal), at Stone Carr, and west of Dunswell (Figure 13). There are no substantial areas of “new” inundation due to climate change, with the exception of Thearne; floodwater originating from overtopping of the Beverley and Barmston Drain is directed towards Sicey Farm via minor field drains (including the Beverley and Skidby Drain) where it accumulates to produce flood depths of up to 0.6 m.

*Figure 13 - Flood inundation prediction for 1% AEP event with climate change*
4.5.8 As the strategy is reviewed, the opportunity will be taken to incorporate the most up to date Defra estimates of sea level rise and rainfall uplifts.

4.5.9 Alongside this both Local Planning Authorities (LPAs) have a protocol in place with the Environment Agency that provides a screening process that helps determine which planning applications need to be referred to the Agency for comment or advice. The Agency is also a statutory consultee as LPAs develop their Local Plans and related strategies. The LPAs’ Strategic Flood Risk Assessments also inform developers and development on actions that must be taken to allow development to proceed in flood risk areas.
SECTION 5: HYDRAULIC MODELLING

5.1 Introduction

Client requirements

5.1.1 This approach is supported by the RHICS multi-agency project board who have chosen the proprietary InfoWorksICM© modelling platform, this is to allow consistency across both districts where InfoWorksICM has already been used to produce verified results. All principal modelling for the current study has, therefore, been conducted using InfoWorksICM© (4.0.3.8010 Unicode October 2013).

Modelling context

5.1.2 The River Hull and Holderness Drain Flood Mapping Study (2013) forms the basis for the current ICM modelling. That study utilised an ISIS-TUFLOW© model of the River Hull and Holderness Drain catchments, upon which subsequent InfoWorksICM© modelling is based. The original ISIS-TUFLOW© model was constructed using:

5.1.3 An existing ISIS©-1D model (Halcrow 2011) - From the River Hull Strategy which, as part of the Hull Hydrology and Data Investigation study, was updated in April 2011.

5.1.4 River cross-sections - These are based on a combination of bathymetry survey data in the lower sections of the Holderness Drain and River Hull, and supplementary cross-section surveying further upstream. The cross-sections used are based on topographic survey data from various years. The cross-sections on the River Hull are based on surveying undertaken in 1997 and 1999. A more recent bathymetric survey of the Hull was also undertaken in 2009. For some drains survey information was not available, therefore such channels had their cross-section data generated using a highly detailed Digital Terrain Model (DTM) obtained using aerial surveys. Adjustments were made to the drains in order to represent the bed levels more accurately. The DTM data is formed of a grid, with a vertical accuracy of approximately 0.05m and a resolution of 0.25m.

5.1.5 Surveying (and other available information such as LiDAR and aerial/street photography) - For the representation of orifices, flap valves, weirs, culverts, bridges and other structures. Dimensions for any culverts or outfalls on the smaller Internal Drainage Board (IDB) drains were generally estimated in the model. A survey of the hard defence levels on the River Hull and the following structures was undertaken in 2010 and 2011: Hedon Road outfall, High Flags outfall, Monk Dike weir, West Beck weirs, Driffield Canal lock gates and Driffield Canal bypasses.

5.1.6 2m resolution LiDAR data - Used to generate a 15 m x 15 m regular 2D ground surface grid with appropriate connections to the river domain. Most of the LiDAR data covering the 2d modelled floodplain is from either 2006, 2008 or 2010. The 2008 and 2010 data cover all of the urban area of Hull and its surrounds. LiDAR vertical accuracy is generally in the range 5cm to 15cm.

5.1.7 Additional surveying - To define and represent road/rail embankments, culverts through these embankments, and minor channels.

5.1.8 And was:

5.1.10 *Validated* - As part of same 2010 study as above for Feb 2002 and June 2007 events.

5.1.11 For consistency across the catchment, there is a desire to convert the existing model into ICM. Conversion into ICM will also facilitate the eventual integration of the river model with existing surface water and sewer network models, which are constructed in either ICM or InfoWorks© CS (noting that CS networks can be imported with 100% functionality into ICM).

5.1.12 The ICM model utilises the same boundary condition and input data as for the ISIS-TUFLOW© model:

   a) FEH-derived design event inflow hydrographs
   b) Nominal downstream tidal boundary condition (high spring tide), based upon River Humber water level recordings at Albert Dock.

5.1.13 Constant design permeable baseflow inputs at 20 locations, derived from records at Snakeholme (the catchment of which is permeable and exhibits a baseflow dominated response). These were derived by the application of FEH statistical methods gauged at Snakeholme. The Environment Agency’s River Hull catchment groundwater model (developed by ESI Ltd) was utilised to spatially distribute flows based on the design accretion profile. Baseflows were applied in modelling as constant inflow boundaries, such that the design baseflows match Snakeholme estimates. Initial conditions were based on a fluvial baseflow steady-state condition.

5.2  **Model construction**

5.2.1 The current study employed the ISIS-TUFLOW© model as a starting basis, with the objective of model construction as follows:

   a) Convert/import the ISIS component of the model into ICM
   b) Replicate 2D TUFLOW features (road/rail embankments, embankment culverts and minor channels) within the ICM 2D domain
   c) Extend the 1D domain to explicit represent agreed-upon additional channel sections
   d) Extend the 2D domain to cover the potential pluvial catchment area bounding the modelled 1D extent of the River Hull and Holderness Drain systems (in effect, the extent covers the full catchment for both systems, removing boundary sub-catchments already accounted for by direct fluvial inflow at a terminating upstream node.

**Conversion of ISIS-TUFLOW© to InfoWorksICM©**

5.2.2  *River cross sections* - Georeferenced ISIS river cross-sections can be imported directly into ICM via an integrated import tool. For some sections without full geo-referencing (i.e. without easting and northing coordinates), locations were inferred from neighbouring georeferenced cross-sections and reach distances provided in ISIS.

5.2.3  *Flow control structures* - Some flow control structures, such as weirs, sluices and culverts, are represented identically in ICM. Others, such as orifices and flap valves, are assumed to be of rectangular aperture in ISIS (e.g. defined by invert level, soffit level and bore area) but circular aperture in ICM (e.g. defined by invert level and diameter). Full equivalence in representation is therefore not possible, with the ICM model build being
based on a matched invert level and diameter equivalent to the ISIS bore area. Bridge representation in ICM requires five cross-sections (a contraction reach, upstream face, deck profile, downstream face and expansion reach); the contraction reach, upstream face and expansion reach are directly provided from ISIS cross-section and bridge information. For the ICM model build, the cross-sectional profile of the downstream face is assumed to match the upstream face, translated spatially to the correct location.

5.2.4 **Floodplain/2D domain** - There is no equivalence between the grid-based 2D zone representation in TUFLOW and the flexible (variable-sized polygonal elements built from component triangles) meshing employed to represent 2D zones in ICM. However, 1D and 2D structures accounted for in the TUFLOW 2D domain – for example, road/rail embankments including relief culverts through these features, as well as minor channels not explicitly represented in the 1D domain – were imported and represented in an identical manner within ICM.

5.2.5 **River embankments** - The existing ISIS-TUFLOW© employs multiple methods to represent the interface between the 1D river/drainage channel elements and 2D domain. Representation of this interface in ICM was achieved by a combination of direct import of bank lines from TUFLOW as well as extraction and import of bank spills from various reaches of the ISIS model.

**Model extension and surveys**

5.2.6 Topographic surveying of data gaps was undertaken by Grontmij in April 2014. This included cross-sections on the following channels: Ganstead Drain, Wawne Drain, Old Main Drain, Crofts Drain, Engine Drain, Mickley Dike, The Beck, Driffield Beck, Gypsey Race, Driffield Trout Stream, Sisterbeck Drain, South Bullock Dike, Mill Dam Drain, Beverley Beck and Western Drain. Cross-sections were taken at approximately 200m – 250m intervals where possible; however, access constraints often led to cross-sections being taken at less consistent intervals.

5.2.7 To account for the catchments contributing to Beverley (entering the town at Hurn Gate and Pasture Terrace), additional topographic surveying was undertaken in these locations. As the catchments are then culverted through Beverley as part of the surface drainage network, it was necessary to add these elements of the network to the ICM model. This includes the culverts along Woodhall Way (flowing north to the Sisterbeck Drain) and Manor Road (flowing south towards the Mill Dam Drain).

5.2.8 Bathymetric surveying of the lower reaches of the River Hull was also conducted by Pell Frischmann in July 2014, to capture changes due to sedimentation and the sinking of various barges upon the flow profile of the river relative to the 1999 bathymetry used in previous modelling studies. This updated bathymetry post-dated construction of the existing (“baseline”) condition model, such that option analysis was based on 1999 bathymetry data; instead, the impact of bathymetric changes was assessed via separate scenario analysis. Additionally, 2014 bathymetric data was used by Pell Frischmann to develop a proposed dredged bathymetry, which was assessed as a potential mitigation option (i.e. Option 6).

5.2.9 Further cross-sections based on LiDAR were also added to the model. These were taken to supplement the additional topographic surveying undertaken in April 2014, where data was limited or access prevented. Channels with additional LiDAR sections are: Gypsey Race, Driffield Beck, The Beck, Western Drain, Old Main Drain, Sisterbeck Drain, Mill Dam Drain, Crofts Drain, Engine Drain, Wawne Drain, and Ganstead Drain. LiDAR cross-sections were taken at intervals which “filled the gaps” in the topographic survey results.
5.2.10 Other channels were represented in the model utilising only LiDAR cross-sections. These channels are: Lambwath Stream, Kelwell Drain and Bowlams Dike in the Holderness Drain catchment. In the River Hull catchment, the LiDAR channels are: Nafferton Slack, Nafferton Highland Stream Drain, Bryan Mills Beck, Catchwater Drain, Scorborough Beck, Creyke Dike, Pick Hills Drain and White Dike. These sections were taken approximately every 250m.

5.2.11 This essentially fluvial and baseflow driven ICM model, was utilised for the optioneering phase of the project. The final optioneering modelling required incorporation of the network components. The integrated catchment model (Figure 14) encompasses main rivers and drains (blue); as well as additional rivers (red); 2D rainfall mesh with ground infiltration; sewer networks; fluvial; baseflow and tidal boundaries; and point source upper catchments.
Integration of network model components

5.2.12 Two sewer models were provided by Yorkshire Water for this study: the ‘City of Hull, All Hull’ combined model and the ‘Beverley Flood Alleviation Scheme’ sewer model. Additional sewer network models (Driffield, Leconfield, Leven, Skirlaugh, Tickton, Nafferton and Hutton Cranswick) were constructed by Grontmij from asset data provided by East Riding Yorkshire Council. These models were constructed to Yorkshire Water’s Mathematical Modelling Procedures for Sewerage Systems, specification version 2.0 (October 2009).

5.2.13 For the City of Hull, an all node Type II (Drainage Area Planning (DAP)) model was constructed for each of the seven DAP catchments which drain to Salt End (Hull) WwTW. These models used Yorkshire Water SNRS asset data, with key assets and ancillaries’ surveyed for the purpose of their individual studies. The 7 individual DAP studies were combined together to produce the All Hull model. The All Hull model catchment covers an area of approximately 71 km². The principle watercourses in the catchments are the River Humber and the River Hull. The River Humber borders the southern perimeter of the catchments with the River Hull running broadly through the centre section, from north to south. The River Hull flows into the River Humber.

5.2.14 There are also several other smaller watercourses in the catchments discharging into the River Humber, the River Hull, and also into the combined drainage system. These include: Creyke Beck, Mill Beck and Castle Hill Drain (in 327 Cottingham Drainage Area Zone (DAZ)), Cottingham Drain and Setting Dyke (in 440 Hull West 2 DAZ). The total population of the All Hull model catchment is approximately 386,000 (according to the
EA draft FRMS 2010). The catchments primarily drains under gravity via the Hull transfer tunnel to Salt End (Hull) WwTW. Flows from 438 Bransholme DAZ are pumped through 437 Hull East DAZ, whilst flows from 433 Hedon DAZ are pumped directly to the WwTW. In times of high flow, West Hull and East Hull pumping stations lift flows to the Humber Estuary. These assets are only operated by prior approval.

5.2.15 In order to integrate the 1D model of the YW system into the developed 2D model all the nodes with a flood type of stored or lost were set to a flood type of 2D. This permits flows from the overland mesh to enter a manhole via the weir equation, similarly the manhole can flood on to the mesh should the 1D network capacity be exceeded. The primary adaptation of these models into the RHICS ICM occurred through:

a) CSO and surface water flows directed into modelled watercourses or open drains
b) Fluvial and baseflow inputs for the watercourses are reduced by the areas of the sub-catchments in the towns contributing to sewer or surface water system flows
c) Urban areas have defined sub-catchments with rainfall-runoff inputs to 2D nodes, as well as pervious areas with direct rainfall
d) Building voids have been generated for use in the final combined model, although have not been used in the optioneering model. The voids were generated from OS Master Map data, and include the urban areas within the study area.

Validation

5.2.16 The fluvial driven version of the ICM model is, primarily, a direct conversion of the ISIS-TUFLOW© model. As such the model validation compared predicted water level time series between the ISIS-TUFLOW© model and the ICM model at a number of cross-section locations in the River Hull, Holderness Drain and Beverley and Barmston Drain systems. This comparative assessment, conducted using the existing condition model for the 100 year design fluvial runoff event, indicate minimal (<0.03 m) variation in peak water level predictions, with variations in antecedent water levels typically less than 0.05 m.

5.2.17 A model validation exercise was also carried out by using the new ICM model to simulate the June 2007 event and then comparing the model results to the observed water levels and flood outline. The June 2007 event is the most recent major flood experienced in the catchment with an estimated return period of between 1:50 and 1:300 across the catchment for the Flood Events from the 13th to 26th.

5.2.18 The June 2007 event was simulated using rainfall inputs to drive the model inflows and representation of the pumping stations as accurately as possible, using pump telemetry data, specifically the pump operation signal log, collected from the Environment Agency. These signal logs were used to derive time series data for the pump units in the model. Pump telemetry data was available for pumps at Tickton, Great Culvert, Wilfholme and Hempholme pumping stations. Pump telemetry data were not available for Waterside PS as this is owned by Yorkshire Water so the rules were left at the default values. Telemetry data were also not available for East Hull PS for the June 2007 event.

5.2.19 Observed and modelled peak water levels for the June 2007 event show that modelled peak water levels are within 300mm of observed peak water levels with the exception of Foston Mill (near Foston on the Wolds) where high flows are not accurately gauged and on Beverley & Barmston Drain at Beverley Shipyard and at Waterside PS where the differences are 350mm and 370mm, respectively. Given that good validation is achieved
at all other locations and considering the uncertainty in flood volumes into Beverley & Barmston Drain, which is ungauged, the model is considered to be sufficiently validated. Furthermore, the modelled flood outline for the June 2007 event closely followed that produced by the Environment Agency.

5.2.20 A third party peer review of the modelling methodology will be undertaken after adoption. An EA-appointed framework consultant will likely carry out the work with the partnership’s modelling consultancy to look at the model’s inputs and outcomes. This peer review will provide a separate summary report into findings.
5.3 Design event and modelling of existing condition

Boundary conditions

5.3.1 Three types of design event are considered in the modelling: fluvial runoff, fluvial baseflow and tidal. As such, the boundary conditions of the model comprise fluvial runoff hydrographs, fluvial baseflow inflows, and a tidal signal as the downstream condition.

5.3.2 In order to model each type of design event separately, inputs for the type in question are set to the required return period, with the other two inputs being set to nominal values. For example, the 100 year fluvial event would comprise a 100 year fluvial runoff hydrograph, while a nominal fluvial baseflow and nominal tide would also be applied.

5.3.3 For the baseline model runs, the tidal signal was taken as a nominal tide (i.e. a high spring tide) at Albert Dock (Figure 16 below).

![Tidal boundary condition for fluvially dominant design events](image-url)
5.3.4 Baseflow values are also assumed to be nominal for the baseline runs, as defined in the previous River Hull and Holderness Drain Flood Mapping Study. The nominal fluvial baseflow was defined as a proportion of the two year baseflow values by comparing values for the 14-day moving average combined flows at Snakeholme for the two year return period with the 14-day moving average combined flows at Snakeholme for the mean flow.

5.3.5 Baseflows are applied as a constant throughout model runs. There are 20 catchments which contribute baseflows to the model, as described in Table 10. For the baseline scenario, nominal baseflows are equal to approximately 6.04m$^3$/s in total. The baseflows for the other considered return periods, which are only used in baseflow dominant model runs, are also displayed in Table 10.
Various return period events, most significantly the 1% AEP, were included in the model in the form of hydrographs at several locations. These locations were previously defined in the River Hull and Holderness Drain Flood Mapping Study. In total, 37 sub-catchments comprise the entire River Hull catchment, while eight sub-catchments make the Holderness Drain catchment. The combined hydrographs for each catchment are displayed below in Figure 17. For the 100 year event, a total peak flow of approximately 95 m$^3$/s is predicted in the River Hull Catchment, while in the Holderness Drain catchment this value is approximately 60 m$^3$/s.

<table>
<thead>
<tr>
<th>Baseflow Model Inflow Location</th>
<th>Nominal</th>
<th>5 Yr</th>
<th>10 Yr</th>
<th>50 Yr</th>
<th>100 Yr</th>
</tr>
</thead>
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<td><strong>TOTAL</strong></td>
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<td><strong>19.460</strong></td>
<td><strong>22.990</strong></td>
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Figure 17 - Combined catchment hydrographs for fluvially dominant design events
Due to the excessive computation time associated with modelling such a large spatial extent, a simplified common model was used for optioneering, including for the representation of the existing (“baseline”) condition. This model employs a 2D mesh discretisation, with a minimum element area of 100 m² and maximum triangle area of 2000 m². Void polygons, which represent buildings within the 2D domain but results in a substantial number of extremely small mesh elements due to their close proximity to one another, are also disregarded in meshing in the simplified model.

Pluvial inputs are applied to the Hull & Haltemprice catchment directly on to the 2D mesh, and through drainage sub-catchments within the environs of the City of Hull, both east and west of the River Hull. Similarly other built up urban areas, such as Beverley and Driffield, within the wider River Hull catchment have pluvial inputs applied. Where there is an overlap of fluvial inflow catchments with pluvial areas, such as at Beverley, the area defining the fluvial inputs hydrographs are adjusted downwards, thereby ensuring that no addition inflows are applied to the model.

**Initial conditions**

Initial conditions for the fluvial-only model are based on warm-up runs consisting of:

a) High (winter) fluvial baseflow, applied as a constant inflow at all fluvial inflow locations within the model

b) Nominal tidal fluctuation at the River Hull and Holderness Drain outfall points, ensuring that tidal levels at the end of the warm-up run match initial tidal levels employed in the actual design event simulation

The final state of the warm-up run is used as the initial condition for design event simulations. For the integrated model, initial conditions are established by a sequence of two warm-up phases:

a) The first phase of warm-up is identical to that described for fluvial-only runs, and is used to establish appropriate initial conditions in the river/surface drain system

b) The second phase of warm-up uses the final state of the first phase as its initial condition. Constant fluvial baseflow and tidal fluctuations continue, with rainfall from the period 19 to 31 November 2012 used to establish initial conditions within the surface water and combined sewer network elements of the model. Note that rainfall was only applied to network sub-catchments, and not to the 2D mesh itself, such that a given design event simulation is assumed to commence with appropriate fluvial-tidal and network initial conditions, but with no antecedent pluvial flooding. Tidal fluctuations in this second phase are timed to ensure that the initial tidal level matches the final tidal level of the first phase and that the final tidal level matches the required initial tidal level for actual design event simulations.

**Integrated model design**

For integrated fluvial-pluvial-network flood risk modelling, design events of two different durations were considered for each return period:

1. A 75 hr duration design event, representing the critical event duration with respect to fluvial flood risk
2. A 10 hr duration design event, representing the critical event duration with respect to network flood risk, noting that the integrated model includes surface and combined sewer networks
5.3.12 By definition, a given annual exceedance probability event has an equal probability of having any particular duration, whether equal to any of these critical values, or more or less than either. As a worst case, assessment should consider flood inundation that can result from either of these two critical durations. With simulations for each design event duration providing a maximum inundation depth estimate, flood damage estimation should be based on the maximum of these two estimates.

5.3.13 Predicted inundation for the 75 hr critical duration event essentially mimics fluvial-only predictions, with some alteration due to reductions in fluvial inflows (offset by the inclusion of pluvial runoff) and refinement of bank definitions, with the addition of pluvial and network flood inundation in some urban locations. However, network flooding is more extensive for the 10 hr design event, as higher peak rainfall excess intensities (relative to the higher total volume but lower intensity 75 hr event) exceed the abilities of individual sewer pipes, network branches and/or pumping stations to either store or conduct the drainage they receive.

5.3.14 Pluvial flooding and network flooding is spatially discontinuous, occurring in countless small patches throughout the sewer service area and in isolated topographic depressions. However, larger patches of flooding are predicted in some areas:

a) West of the railway embankment, from Gengs in the north to Willerby Road in West Hull
b) Immediately south of this, around Anlaby Road, west of Calvert Lane
c) Linear pluvial flood traces within topographic depressions, representing minor land drainage channels not explicitly represented in the fluvial model, particularly in the vicinity of Skidby.

5.3.15 Climate change is predicted to increase the extent of large patches of inundation, as well as creating a greater number of small, isolated patches of inundation throughout the sewer service areas of all included network systems. Although the volumes of increased inundation will be relatively small, their occurrence within high-value urban areas will substantially increase associated flood damage. While supplementing the pump capacity of network pump stations may help alleviate flooding associated with future climate change, increased peak rainfall intensities – and hence inflow rates – will result in an increasing proportion of network flooding being associated with local conveyance.
limits within individual sewer pipes and sewer network branches, making network flood mitigation with respect to climate change more complex and costly than fluvial flood mitigation.

5.3.16 As an example of how such issues are being addressed, the City Council and Yorkshire Water are working with local communities to explore how local sewer network flooding hot spots can be addressed, using the Floodbus as a mobile meeting venue. In addition, the second stage of Yorkshire Water’s Hull & Haltemprice urban drainage study will allow partners to explore network-wide potential solutions.
SECTION 6: ECONOMIC APPRAISAL

6.1 Introduction

6.1.1 Economic appraisal of options has been undertaken in line with the Environment Agency’s Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG), the supplementary guidance to the FCERM-AG and by reference to the methodologies contained within the Multi-Coloured Manual (MCM) and Multi-Coloured Handbook (MCH) published by the Flood Hazard Research Centre (FHRC) in 2013.

6.1.2 The flood events analysed were 20%, 10%, 2% and 1% AEP. Additional datasets were available for the 100% AEP for use within the assessment of agricultural impacts.

6.1.3 For the purpose of this economic assessment climate change is considered by assessing the consequences of increases to rainfall intensity, fluvial in flows and sea levels 100 years into the future in line with guidance presented in the Environment Agency’s Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities (2011) on how climate change may affect these parameters.

6.2 Residential damages

6.2.1 The damage caused to residential properties by flooding is calculated by establishing the depth of flooding at each property. This is achieved by processing the flood modelling outputs obtained from the River Hull Integrated Catchment InfoWorks® ICM model in GIS format to first identify those properties present within the Environment Agency’s National Receptor Database (NRD) and specifically those within the NRD Property Points dataset.

6.2.2 Properties within the floodplain have the depth of flooding identified which is then converted into a damage value using up-to-date depth-damage curve information available from the MCM (2013). The depth-damage curve profiles for different types of property (detached, semi-detached, terrace, flat etc.) are applied based on the type of property affected.

6.2.3 This process is applied for each modelled scenario and for each return period. Property damages for each event are converted into an average annual damage (AAD) for each property that is then discounted over the next 100 years (using the discount values specified by Defra from The Green Book (HM Treasury, 2011) to calculate the Present Value of Damages (PVD). PVD is capped at the value of the property if the calculated PVD exceeds the value of that property. The capped PVD is then summed to provide an overall PVD for each scenario.

6.2.4 The base data used in the assessment includes:

- A digital terrain model (DTM) for the catchment in the form of LiDAR data
- Water level and depth outputs from the hydraulic modelling, provided as a vector layer in GIS software
- National Receptor Database (NRD) provided information on the location and type of properties; and
- Ordnance Survey Mastermap® data.

6.2.5 For the purposes of the economic assessment the DTM available to the study has been used to define the average ground level at each property.
6.2.6 Water level and depth information was obtained from the model outputs in order to assess the values of these parameters at each property affected. Because of the manner in which outputs are extracted from InfoWorks ICM, flooding depth at each property was ultimately derived by subtracting the average ground level at each property (defined by inspection of the underlying LiDAR) from the modelled water level. This avoided any issues of over- or underestimating depth that it was noted could occur if the depth outputs were used directly.

6.2.7 The NRD provided information on the location and type of dwelling affected by flooding which is then used within the damage calculation. The final property dataset covering the study area included 223,721 properties, of which 179,403 are identified as dwellings, though not all are affected by flooding. The dataset was reviewed and modified to ensure that properties that were identified as dwellings but with alternative uses were not included.

6.2.8 Thresholds levels of dwellings are not defined within the NRD. Initial PVD estimates were undertaken on the assumption that the threshold level was the same as the ground level at each property, however, for the full assessment a survey of approximately 250 properties was undertaken for 14 built-up areas within the floodplain. The survey selected a random sample of properties within these areas and, using Google Streetview as the principle source of information, estimated threshold levels for these properties. The distribution and nature of thresholds was reviewed and the outcome incorporated into the PVD assessment.

6.2.9 It is acknowledged that this approach will not produce a precise estimate of thresholds at each property; however, it will be recognised that any inherent error in the estimate of threshold will tends to err towards a reasonably consistent estimate of average threshold value as the number in the sample increases. Hence the impact of property thresholds on internal flood depth and therefore flood damage estimates can be accounted for. Further sensitivity testing highlights the impact of refining thresholds on damages.

6.2.10 The value of property, used in the process of capping PVD by property value in the event that the PVD exceeds the property value, has been based on the average property price by property type for the Yorkshire and Humber Region, as defined by the Land Registry (www.landregistry.gov.uk) for the period May 2014.

6.2.11 PVD calculations exclude upper floor properties, as these are not expected to experience damage. Upper floor properties have been identified using information on floor level within the NRD dataset.

6.3 Non-residential damages

6.3.1 The damage caused to non-residential, commercial properties by flooding has been calculated in the same manner as for residential properties, however, a different set of up-to-date depth-damage curve information (MCM, 2013) is used.

6.3.2 Depth-damage curve profiles are specific to the land-use sector of the property impacted and again a depth-damage profile that included an allowance for salt damage have been utilised. Under the latest guidance, depth-damage curves are available for the following land-uses:

a) Retail
b) Office
c) Warehouses
d) Leisure and Sport, including for:
   • Playing fields
   • Sports Centres
   • Sports Stadiums; and
   • Marinas

e) Public Buildings

f) Industry; and

g) Miscellaneous, including:
   • Car Parks; and
   • Sub-stations.

6.3.3 As with impacts to residential damages, property damages for each event were converted into an average annual damage (AAD) for each non-residential property (NRP) that was then discounted over the next 100 years (using the discount values specified by Defra from The Green Book (HM Treasury, 2011) to calculate the Present Value of Damages (PVD)).

6.3.4 Unlike residential properties, PVD is capped at the rateable value of the property, which has been obtained from information available on the Communities and Local Government website (CLG, https://www.gov.uk/government/statistical-data-sets/live-tables-on-commercial-and-industrial-floorspace-and-rateable-value-statistics).

6.3.5 Given the large number of NRPs within the study area (44,318), this approach allows the area of the property to influence the damage estimate in a way that average bulk classes available from the Valuation Office Agency (VOA) do not. No uplift from 2008 to 2014 prices has been applied, as business rates have not increased significantly over the last 6 years because of the economic downturn.

6.3.6 Rateable value reflects the rental value of the commercial property, which is assumed to amount to around 8% of the property value or a position where the value of the property is repaid after 12.5 years. Consequently, bulk class rateable values are multiplied by a factor of 12.5 to define the capped value of PVD.

6.3.7 The base data for the assessment is the same as for residential properties. As with residential properties, but to a greater degree, the NRD land use class information was reviewed and modified to ensure that NRP properties were classified within the appropriate MCM sector, i.e. retail, office or another use.

6.3.8 As indicated above, thresholds levels of commercial properties are not defined within the NRD. Unlike residential dwellings, where threshold levels may vary, it has been assumed that all commercial properties are located at ground level, as reflected by the LiDAR level for the property. It is acknowledged that some businesses will be located within buildings that were once dwellings or which have a threshold level that lies above ground level, however, many or most will not.

6.3.9 The effect of this assumption is tested further through a process of filtering and review of those properties that contribute the highest value to PVD. These are investigated to ensure that they are classified into the correct sector, that the area is appropriate and that the assumption regarding threshold levels is appropriate. This filtering process specifically focussed on the 100 highest contributors to PVD. Aerial mapping photography and where available street viewing software was used to check the nature of the property, to confirm its existence and the land use.

6.3.10 Following this filtering and review process, MCM codes were adjusted where found to be incorrect. To ensure that Sector 9 properties better reflected the data reviewed,
the depth-damage curve applied to Sector 9 properties was adjusted to reflect the nature of the properties identified in that review of the top 100 contributors. Of these 4% didn’t exist, so had no cost associated with them, 2% were dwellings so had the average residential property depth-damage curve applied (using a £/m² value). The remainder utilised the average non-residential property depth-damage curve, which was chosen in preference to a weighted depth-damage curve from observed NRP sectors in order to avoid excessively high damages from electricity sub-stations which are explicitly identified in the NRD and covered separately.

6.3.11 Where NRPs had a zero area then where possible a value from the relevant property in the available OS Mastermap® data was used. Because of the sheer number of properties, those for which an area remained unavailable were left as zero so that they did not contribute towards a PDV calculation. The effect of this would be to reduce the PVD and ultimately to marginally reduce the calculated benefit-cost ratio (BCR).

6.4 Agricultural damages

6.4.1 The FCERM-AG supplementary note to operating authorities Valuation of Agricultural Land and Output for Appraisal Purposes (May 2008), indicates that there are three scenarios to consider with regards to the impacts on flooding to agricultural land:

- Scenario 1: Land is abandoned or no longer fit for agricultural purpose for the foreseeable future – this is land that is written off as worthless as a result of frequent flooding
- Scenario 2: Occasional losses of output as a result of flooding – this is land flooded in less frequent events where there is considered to be a reduction in yield for a period; and
- Scenario 3: Agricultural output per hectare either; a) falls as a result of increased flooding incidence or occasionally; b) rises as a result of land drainage that is implemented in response to necessary FCERM activities. This is a more permanent change in comparison to Scenario 2.

6.4.2 The latest MCM guidance provides guidance on the application of the above scenarios, which can be summarised as:

a) Calculation of the value of the land abandoned
b) Calculation of the gross margin of the crops lost as a result of flooding; and

c) Estimating the reduction in gross margin as a result of changes to productivity.

6.4.3 The approach taken in this assessment considers the following methodology:

6.4.4 **Scenario 1**: In this study, land flooded in a one year flood event is considered to fall within this category. This is primarily because this is the lowest event that can be simulated using this modelling approach but also because this defines the area that would be flooded at least once per year if not more and as such, according to Table 9.1 of the MCM is less tolerable for even extensive grassland use.

6.4.5 The area affected by flooding in this scenario is essentially written off and the damages are equal to the market value of land of similar quality. In order to define this value, a review of three sources of agricultural land value in the East Riding of Yorkshire was undertaken:

a) RICS/RAU Rural Land Market Survey Lite H2 2013;
b) RICS/RAU Farmland Market Directory of Land Prices H2-2013; and
c) Farmers Weekly guidance on H2 2009 prices by County9.

6.4.6 The lowest value, that presented in Source 1, was adopted for land value in H2 2013, giving a value of £7,250 per acre. This was adjusted to May 2014 prices using a ration of CPI and converted to applicable units (ha), giving a value of £17,985. Using information presented in Source 3, this market value was converted into a value for land of different quality:

a) Prime Arable: £17,985
b) Average Arable: £15,416
c) Poorer Arable: £14,560
d) Prime Pasture: £16,272
e) Average Pasture: £13,702
f) Poorer Pasture: £11,134

6.4.7 Following guidance presented in Table 9.18 of the MCM on the indicative national distribution of agricultural land use by Agricultural Land Classification Grade, and assuming that all Grade 2 uses require Prime Arable, Grade 3 Arable uses require Average Arable, Grade 3 Pasture requires Prime Pasture and Grade 4 Pasture requires Average Pasture, then the following market values prevail and have been used in this study:

a) Grade 2: £17,985/ha
b) Grade 3: £15,630/ha
c) Grade 4: £13,703/ha

6.4.8 All values include a reduction in market value that is equivalent to £600 per hectare, which reflects current agricultural subsidies that cannot be considered.

6.4.9 **Scenario 2:** Has been applied within this study in all areas flooded that do not fall within Scenario 1 by reference again to Table 9.18 of the MCM on the indicative national distribution of agricultural land use by Agricultural Land Classification Grade, however, this is then related to the Flood Cost in £/ha presented in the same table 10. Gross margins used are:

a) Grade 2: £1,053/ha
b) Grade 3: £495/ha
c) Grade 4: £189/ha

6.4.10 **Scenario 3:** Has been applied by reducing the gross margin of land within the flooded areas using information in Table 9.1 of the MCM in combination with those values in Table 9.18 of the MCM. The effect is to reduce the gross margin available for land that is flooded frequently to that available from crops that could grow on land with that risk of flooding. For example, if land is flooded so frequently that high value crops are not viable, then the gross margin is reduced to reflect the crops that could grow on land with that level of flood risk.

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8 This document indicates guide prices for farmland that is for sale, plus an indication of whether it is close, well above, substantially above, well below or substantially below guide price.

9 Adjusted to H2 2013

10 Table 9.18 is based on average damage costs within different Agricultural Land Classification classes based on the summer 2007 floods and including other costs.
6.5 Other damages

6.5.1 A review of other damages has been undertaken; however, given the scale of damages associated with properties and agriculture, plus the fact that there is relatively little difference in the impacts to other receptors between options, no other damages have been incorporated into this assessment.

6.5.2 The same reason applies when considering induced or consequential damages, i.e. impacts on loss of business interruption, loss of trade, additional working hours etc. Guidance in the MCM (2013) indicates that financial losses associated with indirect impacts can amount to approximately 30% of business insurance claims (from analysis of the 2000 and 2007 floods). This would convert to approximately 2% to 6% of total NRP damages and a 3% uplift is conservatively suggested. As there is little difference between options with regards to NRP damage, this additional 3% uplift would not introduce any change in the overall outcome of the assessment and has therefore not been applied.

6.5.3 The MCM (2013) also provides guidance on where further analysis of indirect impacts may be warranted, such as when NRP’s contribute more than 30% of direct damages or where there are specific industrial or manufacturing sites at risk. In this case, NRP’s contribute to approximately 22% of the direct damages in the baseline scenario, which does not warrant specific follow up, and there are only two industrial sites in areas at risk from all the options assessed, again not warranting the additional investment in time to assess consequential losses.

6.6 Risk of life

6.6.1 Risk to life has not been estimated for this study. Whilst it is acknowledged that there will be some risk to life, the nature of the options and the scale of flooding is unlikely to result in significant differences between the risk to life calculated for each option, with the exception of the Do Nothing scenario. Risk to life is therefore unlikely to be a major factor when differentiating options using BCR.

6.6.2 If the BCRs of options appear close then risk to life may become a factor and this decision will be reviewed for the preferred options.

6.7 Costs

6.7.1 Costs have been estimated for each of the options taken forward to be modelled in which there was a more than negligible change in flood risk. Breakdowns of costs can be found in Appendix D and include such items as:

a) Materials
b) Man-power and plant
c) Land purchase
d) Construction
e) Changes in operation
f) Infrastructure and assets
g) Mitigation measures
h) On-costs such as preliminaries, management fees, overheads and contingency costs.

6.7.2 Costs will be exclusive of Optimism Bias unless otherwise stated, it will be applied separately as a blanket value of 60% to capital and maintenance except where costs are clearly known, such as in the case of existing maintenance costs or quotes from sub-contractors. Optimism bias accounts for the overly optimistic perspective of project
appraisers when assessing project costs and it helps to account for uncertainty in relation to factors such as ground conditions.

6.7.3 Costs are applied between year one and year five of the benefit period, except related maintenance costs which are applied from year one for the whole of the benefit period. As with damages, the costs are discounted over the period of the assessment (using the discount values specified by Defra from The Green Book (HM Treasury, 2011) to calculate the Present Value of Costs (PV Cost).

6.8 Benefit cost ratios

6.8.1 A benefit cost ratio (BCR) has been calculated for each Option that has been modelled and for which cost estimates are available. The Do Nothing scenario is the usual basis against which the effect of Do Something Options are tested. Whilst a Do Nothing scenario has been assessed, in this case it has not been used as the baseline against which the other Options are assessed.

6.8.2 The Do Nothing option results in extensive flooding to over 27,000 properties and is not a situation that could ever be considered. As a result, the baseline scenario in this study is considered to be a scenario where the existing standard of protection is maintained and the removal of sunken boats from the River Hull channel has taken place. This mirrors the Baseline scenario of the original River Hull Strategy and reflects a situation that is already in the process of being developed.

6.8.3 The BCR is calculated in the following way:

a) The PVD for the Option under assessment is subtracted from the PVD for the Baseline scenario – this produces an estimate of damages avoided, also known as the Benefit;

b) The Damage Avoided of the Option is then divided by the PV Cost to determine the BCR – Note, the cost estimate excludes whole-life maintenance costs and only reflects the cost associated with each Option and changes in maintenance – whole life costs have been considered separately;

c) If an option has a BCR of less than one then it is not considered to be cost-effective, however, if the BCR is greater than one then the benefits are greater than the costs and it can be considered further;

d) Although a whole-catchment study, some options only impact the Holderness Drain catchment, whilst others impact the Barmston Drain catchment. No application of the Incremental BCR approach has therefore been applied.

6.8.4 Before concluding and considering other factors, potential contributions can reduce the FCERM funding required and can increase the BCR for some options and therefore alter the preferred option. Similarly, the effect of sensitivities, such as climate change, threshold levels and other assumptions should be considered to ensure that the preferred option is robust.

6.9 Benefit apportionment

6.9.1 Apportionment of damages to properties for all sources of flooding is being agreed through a nested approach presented at a Humber-wide level. The principles and progress were reported to LPRG in April 2015. Final values to be used for each source of flooding will be used when applications for funding are made at project level.
7.1 Environmental assessments

7.1.1 A Strategic Environmental Assessment (SEA) was prepared and published by the Environment Agency in May 2010 to accompany the previous River Hull Flood Risk Management Strategy (also of 2010): the ‘River Hull Flood Risk Management Strategy – Strategic Environmental Assessment’. The previous SEA was undertaken in accordance with the Environmental Assessment of Plans and Programmes Regulations 2004 (Statutory Instrument No. 1633).

7.1.2 RHICS has refined and evolved previous strategy options. Following discussion with the appropriate consultees it was agreed that an Addendum to the previous SEA would be prepared to effectively update that report in the light of amended and refined options and changes to legislation and guidance.

7.1.3 A detailed Scoping Report was published by the EA in advance of the previous SEA in 2010 to accompany the River Hull Flood Risk Management Strategy. It has been judged to remain valid. In line with that, only where new ‘significant’ effects have been identified at the strategic level have they been ‘scoped’ into the assessment process. This SEA process has been carried out in parallel with development of the strategic options. The level of analysis has varied according to how far through the option development process particular flood risk management solutions have progressed.

7.1.4 In conformance with ‘The Environmental Assessment of Plans and Programmes Regulations 2004’ and best practice guidance consideration of ‘reasonable alternatives’ was undertaken at an early stage during development of a strategy for the River Hull catchment. It was determined that a number of potential alternatives could not be deemed ‘reasonable’ on the basis that their benefits were minimal or the option could not be justified on cost benefit grounds; hence, in turn, they would stand no chance of obtaining national flood defence funding. For these reasons, no parallel detailed environmental assessment was undertaken. For the sake of consistency, however, a brief environmental appraisal of these ‘unreasonable’ options was conducted retrospectively. The results are included against each relevant option in Section 9 below. Examples include re-engineering the Old Howe so it could drain to the sea as it did previously, diverting Holderness Drain around the eastern side of Hull, and two alternative routes for a new sea cut from near Emmotland to Hornsea.

7.1.5 As the RHICS is taken forward and flood risk management measures are considered in more detail, project specific environmental assessment will take place. In some instances this may take the form of a statutory Environmental Impact Assessment (EIA) and then published in an Environmental Statement. These assessments will include issues which may be more important at a local level, or respond to the detailed design of proposed flood risk measures, but do not influence the selection of a strategic flood risk management approach unless significant effects at a regional level are predicted e.g. legally protected species and local sites designated for nature conservation.

7.1.6 The SEA Addendum has incorporated a number of key changes to reflect both the evolution of strategy options and likely changes to the environmental context since 2010. Specifically these changes have included:
a) An update of the baseline environmental data. More emphasis has been given to non-designates assets which could affect the balance of assessment for various options

b) Consideration of the Water Framework Directive, which seeks to ensure water bodies achieve good ecological status

c) Re-examination of the planning policy background. A number of key policies have changed in the interim four years including, the introduction of new legislation e.g. the Conservation of Habitats and Species Regulations 2010 (as amended 2012), the emergence of new Local Plans, and the National Planning Policy Framework

d) The potential environmental effects and significance of impacts have been reassessed on the basis of the updated baseline information and revised options

e) Necessary revisions to the SEA Monitoring Plan in light of the changes that have arisen through the assessment process

f) Production of a new Non-Technical Summary to reflect the content of the SEA Addendum.

7.1.7 The SEA Addendum necessarily makes a number of assumptions. As indicated above, the existing SEA Scoping Study is considered to be still valid, but is now supplemented by the more recent Scoping Study for the ERYC Local Flood Risk Management Strategy SEA (ERYC – 2014 Draft) and Hull Local Plan Sustainability Appraisal (Hull City Council – April 2014 Consultation Draft). For the purposes of the SEA Addendum these Scoping Studies are taken together to guide the key issues addressed in the assessment process. Additionally the previously identified Environmental Objectives, as outlined in the original SEA, are carried forward into the SEA Addendum to ensure a consistency of approach. These have formed the basis of a new suite of sustainability objectives within the strategy itself.

7.1.8 The SEA Addendum was subject to stakeholder consultation for six weeks in April/May 2015 as part of the wider options consultation that commenced in November 2014. A final version of the SEA Addendum will be published. Monitoring of the SEA Addendum will take place in accordance with the recognised SEA process and current regulations.

7.1.9 As the SEA identified that Option A – River Hull dredging and vessel removal – had the potential to impact on the Humber estuary’s habitat designations (SAC, SPA, SSSI and Ramsar site) a Habitat Regulations Assessment has been undertaken in co-operation with Natural England, and was subject to external consultation. Its recommendations are incorporated into the Option assessment in Section 9 below.

7.1.10 As strategy options and the SEA addendum were developed, it became apparent that there was potential for Option 6 (channel maintenance, including boat removal, silt removal and riparian reed removal) to have an impact on the Humber’s designations, which triggered the need for a Habitat Regulations Assessment (HRA). The project budget had made allowance for this. A brief for the HRA was subject to consultation with Natural England before a contract was awarded. A number of drafts of the HRA were also subject to consultation with Natural England and amended after suggestions were made.

7.1.11 All environmental documents can be found on the East Riding Flood Risk site at http://www2.eastriding.gov.uk/council/plans-and-policies/other-plans-and-policies-information/flood-risk/.
7.2 **Water Framework Directive (WFD)**

7.2.1 The SEA incorporates an assessment intended to meet WFD requirements. Water Framework Directive (WFD) Assessment examines the potential effects of a proposed scheme on the ecological quality of relevant receptor WFD waterbodies. Effects which are likely to reduce the possibility of meeting WFD objectives or otherwise cause deterioration in the status of downstream and groundwater waterbodies are identified and assessed. Table 11 below (Table 6.5 in the SEA) summarises the assessment of the RHICS options against WFD objectives for each effected waterbody.

7.2.2 Each option is assessed against predicted effects on WFD receptors identified in the table and, taking into account mitigation, the residual effect on quality elements for each waterbody has been assessed. It is then possible to determine whether the proposed flood alleviation scheme complies with the overarching objectives of the WFD for each waterbody as set out below.

7.2.3 **Objective 1**: The proposed scheme does not cause deterioration in the WFD Status of the Biological, Chemical and other assessed Elements of the waterbody;

7.2.4 **Objective 2**: The proposed scheme does not compromise the ability of the waterbody to achieve its WFD status objectives;

7.2.5 **Objective 3**: The proposed scheme does not cause a permanent exclusion or compromised achievement of the WFD objectives in other bodies of water within the same RBD; and

7.2.6 **Objective 4**: The proposed scheme contributes to the delivery of the WFD objectives.

7.2.7 The strategic WFD assessment concluded that Objectives were met by each option subject to implementation of a range of mitigation measures.
Table 11 - Assessment against WFD objectives

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Complies with Objective 1</th>
<th>Complies with Objective 2</th>
<th>Complies with Objective 3</th>
<th>Compliance with Objective 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB104026066950 Holderness Drain Source to Fordyke Stream</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Sediment management strategies</td>
</tr>
<tr>
<td>GB104026066800 Holderness Drain from Fordyke Stream to Humber</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Educate landowners on sensitive management practices. Sediment management strategies</td>
</tr>
<tr>
<td>GB104026067130 Garton Wold / Water Forlorns</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Educate landowners on sensitive management practices. Sediment management strategies</td>
</tr>
<tr>
<td>GB104026067060 Driffield Trout Stream</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>None listed – NA</td>
</tr>
<tr>
<td>GB104026067080 West Beck Upper</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Educate landowners on sensitive management practices.</td>
</tr>
<tr>
<td>GB104026067040 West Beck Lower to River Hull</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Educate landowners on sensitive management practices. Sediment management strategies</td>
</tr>
<tr>
<td>GB104026067000 River Hull from West Beck to Arram Beck</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Provide flows to move sediment downstream. Sediment management strategies Maintain sediment management regime to avoid degradation of the natural habitat characteristics of the downstream river.</td>
</tr>
<tr>
<td>GB104026066870 Arram Beck 1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Sediment management strategies.</td>
</tr>
<tr>
<td>GB104026067210 River Hull from Arram Beck to Humber</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Sediment management strategies.</td>
</tr>
<tr>
<td>Groundwater body G41 - GB40401G700700 Hull and East Yorkshire</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>RHICS does not compromise efforts to achieve Good Ecological Status by 2027.</td>
</tr>
<tr>
<td>Chalk</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>RHICS does not compromise efforts to achieve Good Ecological Status by 2027.</td>
</tr>
<tr>
<td>GB5304026093201 T1 Humber Lower</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>RHICS does not compromise efforts to achieve Good Ecological Status by 2027.</td>
</tr>
<tr>
<td>GB5304026093202 T2 Humber Middle</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>RHICS does not compromise efforts to achieve Good Ecological Status by 2027.</td>
</tr>
</tbody>
</table>
8.1 Appraisal process and assessment criteria

8.1.1 Our assessment followed a staged approach, so that undeliverable options could be screened out at an early stage. The options appraisal process is illustrated in Figure 19.

8.1.2 The strategy options were assessed against the following criteria:

a) Technical feasibility
b) Strategic environmental assessment against set environmental objectives
c) Economic viability
d) Risk.

8.1.3 A brief summary of the assessment criteria and process is provided in the following sections; detailed descriptions are included within the relevant Section of this report. Risk is incorporated into the assessment of a) to c) above rather than as a separate process.
Technical feasibility

8.1.4 This relates to whether an option delivers flood risk management benefits and can be implemented from a practical perspective. To test this criterion we considered options against a wide range of technical issues including:

a) Catchment topography and the river/land drainage network, and how this affects flooding processes (is risk transferred elsewhere?)
b) Flood levels and their impact on developed areas and agricultural land
c) The effectiveness of the options in managing flood levels, flood extents or the frequency and duration of flooding
d) The effect of options on infrastructure such as roads, railways, canals and sewage treatment works
e) Build issues of access, land availability and construction methods (can we build the option?)
f) Wider catchment impacts

8.1.5 Only options that are technically feasible and deliverable have been included in the strategy plan.

Environmental acceptability

8.1.6 Although no new scoping framework was developed prior to the generation of flood management options and sub-options, each option was considered for its potential environmental impact – whether any negative or positive impacts were likely to occur, and whether any mitigation might need to be considered. Any option that had potentially significant negative environmental impacts, whether or not unintentional, would jeopardize the whole strategy, not just the individual component.

8.1.7 A Habitat Regulations Assessment was undertaken in recognition of potential harm to protected species and the Humber's designations.

Economic viability

8.1.8 A preliminary cost estimate was produced for each developed option and sub-option or option variation. This permitted early rejection of some options, as modelling showed that equally or more beneficial options could be developed. Examples include a new channel from the River Hull to the coast (recreating Old Howe with an outfall at Barmston, or a new cut from the river to Hornsea).

8.1.9 Other options also failed a benefit-cost assessment as more advantageous or equally or more effective alternatives were available at substantially lower cost; off-line storage lagoons are the principal example. It was clear some option costs could not be justified and would not meet national funding criteria, thus placing the whole strategy at risk.

8.2 Modelling methodology

8.2.1 The hydraulic model was used to help assess options following the outline option appraisal. The model was enhanced several times during the course of the Strategy as new information and knowledge have allowed. Consequently, the models used for some of the earlier stages of the options appraisal are slightly different to the most recent version of the model used to assess the final Strategy options. Although the older versions of the model produced slightly different results to the most recent version, the knowledge and conclusions that have been drawn from the model results are still valid.
This is because the model is sufficiently detailed to be able to represent the differences between the different options and combinations of options considered.

8.2.2 Mitigation options have been developed primarily in relation to fluvial flood risk up to a 1% AEP event. Modelling is also used to determine predicted peak inundation in relation to the 20%, 10% and 2% AEP fluvial design event, to inform flood damage estimation for each option.

8.2.3 For offline storage options, the final option specifications were determined by assessing the predicted peak inundation volume as well as bank spill volume for the 1% EP event for a number of variations of bank spill level. The option progressed in each case is based on the spill level providing the best balance between flood inundation reduction and required offline storage capacity.

8.3 Initial strategic options

Table 12 - Initial list of flood risk management options

<table>
<thead>
<tr>
<th>OPTION Label</th>
<th>Short Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Holderness Drain increased pumping capacities</td>
</tr>
<tr>
<td>2</td>
<td>Holderness Drain improvements</td>
</tr>
<tr>
<td>3</td>
<td>Holderness Drain storage areas</td>
</tr>
<tr>
<td>4</td>
<td>River Hull storage areas</td>
</tr>
<tr>
<td>5</td>
<td>Waterside pumping station changes</td>
</tr>
<tr>
<td>6</td>
<td>River Hull maintenance/conveyance</td>
</tr>
<tr>
<td>7</td>
<td>Embankment raising</td>
</tr>
<tr>
<td>8</td>
<td>Upland storage/natural flood management</td>
</tr>
<tr>
<td>9</td>
<td>River Hull diversions</td>
</tr>
<tr>
<td>10</td>
<td>Holderness Drain diversion</td>
</tr>
<tr>
<td>11</td>
<td>Tidal Sluice</td>
</tr>
</tbody>
</table>

8.3.1 Options appraisal started with discussions amongst the project team to identify concept ideas. These were developed into a list of 11 options at a workshop in May 2014 as shown in Table 12. Further to this, options were developed and reviewed by the team from which sub-options and combinations were produced as shown in Table 13. A surface water pumping option for the Bransholme area of Hull alone was further considered. As was the combination of natural attenuation with the increase in pumping and embankment raising, on the Holderness Drain and storage at the Weel area off the River Hull. Finally the combination of the Weel storage and introduction of the tidal sluice on the River Hull was considered.

Table 13 - Further development of initial flood risk management options

<table>
<thead>
<tr>
<th>Option Label</th>
<th>Short Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Increased pumping capacity (Great Culvert PS and East Hull PS)</td>
</tr>
<tr>
<td>1b</td>
<td>As for (1a), with Tickton PS replaced with flap valve and weir</td>
</tr>
<tr>
<td>1b (22limit)</td>
<td>Variation of 1b, with East Hull PS limited to 22m$^3$/s peak</td>
</tr>
<tr>
<td>2</td>
<td>Holderness Drain re-profiling/widening</td>
</tr>
<tr>
<td>3a</td>
<td>Discounted H Drain storage site</td>
</tr>
<tr>
<td>3b</td>
<td>Holderness Drain offline storage lagoon, upstream of Tickton PS</td>
</tr>
<tr>
<td>4a-d</td>
<td>Discounted River Hull storage sites</td>
</tr>
<tr>
<td>Option Label</td>
<td>Short Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>4e</td>
<td>Offline storage beyond River Hull wetland</td>
</tr>
<tr>
<td>4f</td>
<td>Weel offline storage lagoon</td>
</tr>
<tr>
<td>4g</td>
<td>As for (4f), with increased Waterside PS pump persistence</td>
</tr>
<tr>
<td>5</td>
<td>Increased Waterside PS capacity</td>
</tr>
<tr>
<td>6</td>
<td>River Hull maintenance</td>
</tr>
<tr>
<td>7b</td>
<td>Raise Holderness Drain embankments below Great Culvert PS</td>
</tr>
<tr>
<td>7c-7h</td>
<td>Discounted embankment schemes</td>
</tr>
<tr>
<td>7i</td>
<td>Raise Beverley and Barmston Drain embankments south of Beverley Beck</td>
</tr>
<tr>
<td>7j-7l</td>
<td>Discounted embankment schemes</td>
</tr>
<tr>
<td>8</td>
<td>Upland natural attenuation</td>
</tr>
<tr>
<td>9</td>
<td>Holderness Drain diversion</td>
</tr>
<tr>
<td>10</td>
<td>Upper Hull diversion</td>
</tr>
<tr>
<td>11</td>
<td>Increased utilisation of River Hull TSB (i.e lower activation threshold)</td>
</tr>
<tr>
<td>12</td>
<td>Upland natural attenuation combined with option 1b, 4f and 7b</td>
</tr>
<tr>
<td>13</td>
<td>Bransholme-specific flood mitigation (increased PS capacity)</td>
</tr>
<tr>
<td>14a</td>
<td>Combination of (4f) and (11)</td>
</tr>
<tr>
<td>15a-15c</td>
<td>Removal of Wilfholme and Hempholme pumping stations.</td>
</tr>
</tbody>
</table>

### 8.4 Engineering cost basis

#### 8.4.1

The engineering options above and those that follow in Section 9 have been calculated using the following assumptions in Table 14 below. Detailed descriptions of these assumptions for each of the developed options is available in Appendix D.

**Table 14 - Cost assumptions**

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed sequences of construction operation</td>
<td>High level assumed project delivery method and milestones.</td>
</tr>
<tr>
<td>Source of pricing information</td>
<td>Source of rates and/or estimates, e.g SPON’s Civil Engineering and Highway Works Price Book 2014. Example costs which have been taken into account.</td>
</tr>
<tr>
<td>Other factors that affect rates</td>
<td>Figures, percentages or estimated values for preliminary costs, enabling works, project management, overheads and safety precautions.</td>
</tr>
<tr>
<td>Inflation</td>
<td>Appendix D details whether inflation factors have been taking into account.</td>
</tr>
<tr>
<td>Optimum bias</td>
<td>A 60% optimism bias value has been added to all option totals. HMT guidance recommends a band of OB for all civil engineering works dependent on project difficulty. Working in a marine environment is considered difficult and restrictive and therefore ERYC cost estimate use a figure of 60%</td>
</tr>
</tbody>
</table>
SECTION 9: OPTIONS APPRAISAL

9.1 Assumptions

9.1.1 The mitigation benefits of options progressed from the workshop in May 2014 was assessed quantitatively through hydrodynamic modelling using the fluvial and ICM models described in Section 5. Options were assessed, in the first instance, in terms of their impact upon altering peak floodplain inundation volume in relation to the 1% AEP fluvial design event relative to existing (baseline) predictions. An option is assessed as providing mitigation benefit on the basis of:

a) Complete removal of a given extent of existing flood inundation
b) Non-trivial reduction in peak inundation volume in one or more regions predicted to inundate for existing conditions.

9.1.2 The options were also modelled against the following climate change influences:

a) Three epochs (2055, 2085 and 2115)
b) Predicted sea level rise and rainfall increase
c) Two storm durations (10 and 75 hours).

9.1.3 Options were discarded if shown to produce a non-trivial detriment (i.e. increase in inundation depth or extent) at any location, noting that numerical uncertainty and variations in meshing can result in some small level of artefactual detriment in model predictions that should not necessarily be used to discount any given option. Similarly, options were discarded if modelling indicated no significant mitigation benefit is achieved at any location.

9.1.4 Where predictions indicate that a given option produces a non-trivial benefit, modelling was repeated for 1 in 5yr, 10yr, 50yr and 100yr design events to inform flood damage cost estimation. Separate fluvial ICM model networks were developed for each of the progressed options, with each option using the existing (baseline) model as a basis. Thus, all options assume:

a) Existing flood defence embankments are maintained at current levels
b) Pumping stations are maintained and operated with existing operational rules (except where variation is proposed as a component of an option)
c) The Hull TSB is operational according to existing operational rules (except where variation is proposed as a component of an option)
d) All other control structures, including flap valves, are maintained and remain operational.

9.1.5 The ICM model version used for optioneering did not include an integrated sewer network model, so the initial assessment is primarily in relation to fluvial flood risk and its receptors. The exception is the Bransholme PS option which incorporates the full integrated City of Hull network model and explicit representation of the Holderness Drain.

9.1.6 A final set of combined options were simulated using the full integrated fluvial, pluvial and network model.

9.1.7 For the River Hull options modelling is based on river cross-sections from 1997 and 1999 surveys. The modelled reductions quoted for Options 3, 4, 6, 8, 11 and 14 below
are all based on measurements against these surveys, and not the recent 2014 survey. All the volumetric flood reduction estimates are, therefore, dependent upon dredging back to at least these previous profiles to be achieved. If dredging exceeds the earlier survey profiles, the estimated flood reduction volumes will be exceeded.

9.2 Do nothing (0a)

Description

9.2.1 The “Do Nothing” Option relates to a potential future state in which existing flood defence embankments are left to degrade, and in which active controls are switched off (in the case of pumps) or left open (in the case of sluices). Specifically, the “Do nothing” Option was modelled based on the existing “Do minimum” Option (see below) with the following alterations:

a) All pumps switched off – East Hull, Great Culvert, Tickton, Waterside, Hempholme, and Wilfholme pumping stations
b) The River Hull TSB sluice gate left permanently open/up (i.e. 10 m opening height)
c) Gated weir at Hempholme Weir assumed to be in “collapsed” position
d) Embankment failure modelled at eight specific locations (as per River Hull Flood Risk Management Strategy options Appraisal, May 2010, study), via lowering the appropriate bank to match ground elevations at the external toe of the relevant embankment
e) Outfall flap valves removed (i.e. act as orifices instead) at Beverley and Barmston Drain outfall and Holderness Drain outfall, as well as at Mickley Dike and Watton Beck at their confluence with the River Hull
f) The sewerage system would continue to operate as current.

9.2.2 Note that, under these conditions, substantial flooding is predicted even for fluvial base flow conditions, such that modelling of the “Do nothing” scenario required the development of a different antecedent condition to that used for all other options. This antecedent condition was derived by simulating fluvial base flow conditions continuously in combination with the standard nominal tidal signal until flood inundation extents approximately stabilised.

Cost

9.2.3 No costs were considered.

Economic summary
Table 15 - Do nothing damages

<table>
<thead>
<tr>
<th>Option 0a: Do Nothing</th>
<th>Direct and indirect damages to Property</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PV Damage (£m)</td>
<td>3,465</td>
</tr>
<tr>
<td>Direct and indirect damages to Agriculture</td>
<td>PV Damage (£m)</td>
<td>2,312</td>
</tr>
<tr>
<td>Total</td>
<td>Total PV Damage (£m)</td>
<td>5,777</td>
</tr>
</tbody>
</table>

9.2.4 Table 15 below summarises the economic appraisal of the Do Nothing option.

9.2.5 Under FCERM-AG rules this scenario should be used as the baseline against which the benefits of all other options, including the current baseline option, are compared. As indicated elsewhere in this report, the Do Nothing scenario is not a scenario that could realistically be contemplated. Furthermore, assessment of all options relative to the Do Nothing damages results in large benefits for all options, which obscures the comparison of options against each other and the Baseline. As such, a summary of the economic impacts of the Do Nothing scenario are presented below for information; however, comparison between options later on is relative to the Baseline scenario.

9.2.6 This option results in Annual Average Damages (AAD) to the UK and catchment that are in excess of £330m. The direct economic and financial impacts of this scenario, in addition to the social and in some locations environmental impacts, make this an unacceptable option for further consideration.

9.3 Do minimum (0b)

Description

9.3.1 The “Do Minimum” option entails retention and ongoing operation and maintenance of all existing flood alleviation elements within the Holderness Drain and River Hull system, including:

a) Maintenance of existing embankments
b) Continued operation of existing pumps, flap valves, gated weirs and sluices according to existing operational rules, as appropriate
c) Maintenance of existing channel bathymetry through regular dredging.

Costs

9.3.2 ‘Do Minimum’ still incurs operational costs to maintain the system as it is now. These are:

a) Operation and maintenance costs associated with East Hull, Great Culvert, Tickton, Waterside, Hempholme and Wilfholme pumping stations
b) Operation and maintenance costs associated with River Hull TSB
c) Inspection and maintenance costs associated with all flap valve and gated weir controls
d) Costs associated with maintenance and repair of all existing river/drain channel embankments

9.4 **Withdrawn options**

**Description**

9.4.1 Three options were considered for large scale diversions of catchment flows:

- Route 1 - an upper Hull bypass from Frodingham Bridge towards Skipsea (roughly the route of the former Old Howe)
- Route 2 - an upper Hull bypass from Hempholme to Hornsea
- An East Hull bypass for Holderness Drain

9.4.2 For Route 1 1% AEP peak flows are 8m³/s at Frodingham Bridge. If 50% were diverted, the resulting reduction would have minimal impact on flooding lower down the river. Pumping would be required owing to the adverse gradient. The route would be prohibitively long and expensive, and highly unlikely to meet the necessary cost-benefit criteria, meaning it could not attract national flood defence funding.

9.4.3 For Route 2 the 1% AEP peak flows at Hempholme Weir are approximately 11m³/s. If 50% of flows were diverted 20 km to the east coast, peak flows would be reduced by 5.5 m³/s, which would only reduce flooding lower down the river by a negligible amount. Gradients for the transfer to the eastern coast are not satisfactory, and pumping would be required to convey it to new outfall, particularly for high tides. The route would also be prohibitively long and therefore expensive, and highly unlikely to satisfy necessary cost-benefit criteria.

9.4.4 The option of diverting the Lower Holderness Drain around the eastern edge of the City of Hull would require a separate pumping option to discharge into the Humber, but essentially this would be the same as increasing the East Hull PS capacity option. As with Routes 1 and 2 it is likely to be prohibitively expensive and not meet cost-benefit criteria, and so other more cost effective options were considered to be worth pursuing.

9.4.5 For these reasons no simulations were carried out and these diversion options were dismissed from further consideration.

**Consultation comments**

9.4.6 There was some limited support expressed for re-engineering the Old Howe route so it is made to flow eastwards towards the coast (as it once did), thereby reducing flows into the upper River Hull, but as indicated above, gradients would be inadequate, flooding reduction negligible, and costs prohibitive. There were no comments on the other options.

**SEA appraisal**

9.4.7 As indicated in Section 7, the SEA has undertaken limited assessment of rejected options. Table 6.2 in the SEA shows the analysis. This concludes that there would be potential short term negative impacts on two SSSIs (the Humber and Hornsea Mere), with new or increased biodiversity opportunities from the new watercourses. Potential benefits are not sufficient to outweigh the lack of flood risk benefits or the substantial costs.
9.5 Pumping options (1,5)

Introduction

9.5.1 The Holderness Drain system is, at present, completely dependent upon pumping from the Tickton PS and Great Culvert PS to provide onward flow and prevent substantial flood inundation even in response to mild storm events, as well as being dependent upon pumped outflow from the East Hull PS if fluvial events correspond to high tidal water levels in the River Humber. Other pump stations in the Beverley and Barmston/River Hull systems are also integral to flood prevention in response to extreme events. Two straightforward options may therefore be capable of providing flood mitigation benefit:

a) The provision of additional pumping capacity at one or more PS locations, assuming this doesn’t detrimentally increase flood risk downstream.

b) Alteration to pump operational rules to increase frequency of pumping operation, usually by relaxing pump outlet water level constraints, assuming again that this doesn’t detrimentally increase flood risk downstream.

9.6 Waterside pumping station (5)

Description

9.6.1 An increase in the pumping capacity of the Waterside PS, or else an increase in frequency of pumping operation, may alleviate flood risk to the Beverley area, as well as surrounding agricultural land by reducing peak water levels in the Beverley and Barmston Drain. Noting that pumping at Waterside PS is currently constrained by both the combined capacity of the existing pumps as well as an activation/deactivation
threshold outlet water level, increased pumping can be achieved either by increasing the combined capacity or raising the threshold outlet water level, or both. However, care must be taken to ensure that additional pumping into the River Hull does not detrimentally impact upon flood risk within its catchment.

9.6.2 In isolation, increasing the pump capacity at Waterside PS was predicted to provide limited benefit in alleviating flood risk at Beverley, since increased pumping merely reduces the time taken for the outlet threshold water level to be reached and the pumps to switch off. Conversely, increasing the outlet threshold water level for pump deactivation – either in isolation or in conjunction with increased pump capacity – provides some alleviation at Beverley, but with consequent higher peak water levels in the River Hull resulting in increased inundation depths and extents in upstream reaches (e.g. in Mickley Dyke).

9.6.3 On this basis, all variants of this option were discarded.

**Consultation comments**

9.6.4 Several respondents queried the decision not to take forward this option, especially as Beverley has a growing population. The reasons for rejection are given above, options that cause non trivial detriment and very little benefit were discarded before detailed analysis.

9.6.5 Complaints were received about the Yorkshire Water plant itself and these were passed on to the relevant department. Yorkshire Water is in the process of investigating solutions to increase the capacity of the sewage treatment works, and carried out works including odour control in 2015.

**SEA appraisal**

9.6.6 As indicated in Section 7, the SEA has only undertaken limited appraisal of ‘unreasonable’ rejected options.

9.6.7 For this option, the SEA concluded that negative effects would include the additional area, depth and duration of flooding leading to increased loss of productive farmland, and potential impact on cultural assets. The positive effects may be seasonal habitat creation when the land is wet.

**9.7 Holderness Drain pumping stations (1)**

**Description**

9.7.1 The final variation of this option progressed for full economic assessment is labelled as Option 1b and entails the following alterations relative to the existing (baseline) condition:

- a) An upstream reach, terminating with and drained by the Tickton PS
- b) A middle reach, below the Tickton PS, terminating with and drain by the Great Culvert PS
- c) A lower reach, below Great Culvert PS, drained by a combination of gravitational flow through the terminating flap valve during low tides and pumping by the East Hull PS

9.7.2 Increased pump capacity offers a simple and logical option to reduce fluvial flood risk in the Holderness Drain system. Initial options examined increases of up to 30m³/s in the
combined capacity at all of Tickton, Great Culvert and East Hull pumping stations. A variation was also modelled with Tickton PS replaced with:

a) A 2m diameter flap valve with -2m AOD invert level to provide the primary flow path of water from the upstream reach to the middle reach
b) A 7m wide high-flow weir with 0.45m AOD crest level (i.e. lowering of the existing 7m wide irregular crest weir, which is redundant at present).

9.7.3 This variation was predicted by modelling to produce comparable flood mitigation, and satisfies wider management objectives, and was therefore progressed in preference to the version retaining the Tickton PS. Based on subsequent analysis, it was determined that the East Hull PS maximum pump capacity is limited to approximately 22 m$^3$/s, which corresponds to the estimated conveyance capacity of the interconnecting culvert used to feed the pump inlets at this PS. The trigger levels for the primary pumps of each PS in Holderness Drain:

a) Tickton PS pumps switch on when inlet water levels exceed -1.7m AOD and outlet water levels are less than -0.33m AOD. If pumps are on, pumping continues so long as outlet water level is less than -0.18m AOD and inlet water level is greater than -2.0m AOD.

b) Great Culvert PS pumps switch on when inlet water levels exceed -2.35m AOD and outlet water levels are less than +1.23m AOD. If pumps are on, pumping continues so long as outlet water level is less than +1.45 m AOD and inlet water level is greater than -2.75m AOD.

c) East Hull PS pumps switch on when inlet water level exceeds -0.3m AOD. Pumping continues so long as inlet water levels are greater than -1.0m AOD. (Secondary pumps in each PS have slightly different trigger levels, generally switching on later and switching off earlier than the primary pumps).

9.7.4 If Option 1b/c is implemented, Great Culvert PS trigger levels are altered to increase pump utilisation, with East Hull PS unaltered and Tickton PS removed:

a) Great Culvert PS pumps switch on when inlet water levels exceed -2.5m AOD and outlet water levels are less than +1.33m AOD. If pumps are on, pumping continues so long as outlet water level is less than +1.55m AOD and inlet water level is greater than -2.75m AOD.

9.7.5 A final variation of this option progressed for full assessment is labelled as option 1b and entails the following alterations relative to the existing (baseline) condition:

a) Removal of the existing Tickton PS and replacement with a flap valve (of 2 m diameter, with invert level of -2m AOD) and overflow weir (of 7 m width and +0.45m AOD crest level).

b) Increase in Great Culvert PS peak capacity from existing 12.8 to 18.2 m$^3$/s.

c) Increase in East Hull PS peak capacity from existing 7.5 to 22.0 m$^3$/s.

9.7.6 The existing bypass weir at Tickton PS is very high relative to upstream bank levels, such that removing Tickton PS in isolation will substantially increase flood risk at upstream locations, and will induce significant flooding even during fluvial baseflow conditions. It is, therefore, necessary to provide low-level onflow via a large flap valve to achieve comparable flood risk to existing conditions.

9.7.7 Proposed mitigation measures include the replacement of the Tickton PS pumps with a large flap valve (of 2 m diameter at invert level of -2m AOD). In isolation, this measure
is predicted by modelling to cause no detriment to peak water levels either upstream or downstream of Tickton. On the contrary, and particularly for lower return periods, the flap valve causes an overall reduction in peak water level upstream of Tickton, primarily by permitting higher onflow in the early periods of a given extreme event than is currently achieved by pumping. This greater pre-peak onflow more than balances the cessation of flap valve flow at the peak of the event (i.e. when downstream water levels exceed upstream water levels). Modelling therefore indicates that replacement of the Tickton PS pumps with the proposed flap valve effectively improves the efficiency of flow transfer into the downstream reach. Increased pump capacity further downstream at Great Culvert PS and East Hull PS complement this effect, resulting in further reductions in peak water levels upstream of Tickton.

9.7.8 On a hydraulic performance basis, therefore, there is no rationale for retaining the Tickton PS pumps. However, replacement with a large flap valve does create an additional risk, if the valve becomes stuck in an open position. Modelling predicts higher peak water levels downstream of the valve in response to events of greater than five year return period, such that a stuck valve may significantly increase flood risk upstream of Tickton. Inspection and maintenance of this valve is, therefore, critical to management of flood risk. Table 16 shows the water levels at Tickton from final modelled scenarios.

Table 16 - Tickton levels

<table>
<thead>
<tr>
<th>All figures m AOD</th>
<th>Baseline</th>
<th>Option 1c</th>
<th>Tickton PS replaced with weir only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upstream</td>
<td>Downstream</td>
<td>Upstream</td>
</tr>
<tr>
<td>5% AEP</td>
<td>-0.185</td>
<td>-0.178</td>
<td>-0.235</td>
</tr>
<tr>
<td>10% AEP</td>
<td>-0.168</td>
<td>-0.049</td>
<td>-0.209</td>
</tr>
<tr>
<td>50% AEP</td>
<td>-0.158</td>
<td>0.459</td>
<td>-0.160</td>
</tr>
<tr>
<td>100% AEP</td>
<td>-0.151</td>
<td>0.550</td>
<td>-0.151</td>
</tr>
</tbody>
</table>

Benefits

9.7.9 This option is predicted to decrease peak 1% AEP inundation from the Holderness Drain system by 21%, representing a 1,128,000 m³ reduction. A small portion of this reduction is predicted to occur upstream of the Tickton PS location, indicating that the proposed replacement of Tickton PS with a flap valve and high-flow weir does not cause a detriment when combined with increased pumping further downstream.

9.7.10 While a substantial portion of the total volume reduction occurs on agricultural land and greenspace in the Stone Carr area (between Weel and Wawne) and around the Crofts drain confluence, there is also a sizeable reduction in the flooding extent in high-value urban areas around Bransholme.

9.7.11 A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.
Costs

9.7.12 The capital cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings. The following is a summary of the assumption made in the cost estimates:

a) Works at East Hull PS may cause short term disruption due to locality next to major highway.
b) Decommissioning and other associated costs of closure of Tickton PS
c) Provision and installation of 2m diameter flap valve within the Holderness Drain channel at Tickton PS location, and pipework/channel excavation as necessary
d) Provision and installation of high-flow bypass weir of 7m width at Tickton PS location
e) Provision and operation of additional 5.4 m³/s pump capacity at Great Culvert PS
f) Provision and operation of additional 14.5 m³/s pump capacity at East Hull PS
g) All OPEX costs listed for 0b, excluding operation costs of Tickton PS

9.7.13 Land may need to be acquired by Compulsory Purchase Order (CPO), but is not costed

<table>
<thead>
<tr>
<th>Table 17 - Option 1b capital cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPTION 1b - CAPEX</strong></td>
</tr>
<tr>
<td>Staff Costs</td>
</tr>
<tr>
<td>Consultant fees</td>
</tr>
<tr>
<td>Site investigations</td>
</tr>
<tr>
<td>Construction</td>
</tr>
<tr>
<td>Environmental mitigation</td>
</tr>
<tr>
<td>Site supervision</td>
</tr>
<tr>
<td>Land</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
</tr>
<tr>
<td>60%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
</tbody>
</table>

at this stage.

Economic summary
9.7.14 The following table summarises the economic appraisal of this option.

**Funding and contributions**

9.7.15 Table 19 below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. It also identifies the scale of external contributions required.

9.7.16 Although this option is therefore not fully fundable with FDGiA, there is possibilities to seek additional funding from other sources. It was also agreed to look at adapting this option in order to allow it to acquire a greater amount of Outcome Measure 2’s on the PF calculator, hence this option was taken forward in combination with other FCERM measures. It was further developed as Option 1c where it was amalgamated with option 7b which is included in 9.17 Combined options.

**Consultation comments**

9.7.17 Comments were made on the combined scheme with Option 7b.

**Table 18 - Option 1b economics**

<table>
<thead>
<tr>
<th><strong>Option 1b: Holderness Pumping Stations</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost (£m) 2064</td>
<td>15.0</td>
</tr>
<tr>
<td>PV Benefit (£m) 2064</td>
<td>1.3</td>
</tr>
<tr>
<td>Raw PF Score</td>
<td>34%</td>
</tr>
<tr>
<td>Possible FDGiA Contribution (£m)</td>
<td>5.1</td>
</tr>
<tr>
<td>Required Contributions to realise FDGiA funding (£m)</td>
<td>9.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PV Cost £m</strong></th>
<th>2064</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost (£m)</td>
<td>15.0</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>1.3</td>
</tr>
</tbody>
</table>

9.7.18 The SEA appraisal summary of Option 1b components is included in the section on the combined option 7b.
9.8 Holderness Drain conveyance (2)

9.8.1 Flooding from the Holderness Drain at some locations may be exacerbated by bottlenecks caused by specific locations of lower-than-average conveyance. This option therefore examined whether mitigation can be provided by reshaping of the channel profile to increase bank-full channel width.

9.8.2 As the Holderness Drain is completely dependent upon pumping to provide drainage into the lowermost reach, the pumps themselves represent the primary bottleneck upon the overall conveyance of high flows.

9.8.3 The 1972 East Hull Pumping Station was built as a public asset but is now in the ownership and operational responsibility of YW. At present YW’s pumps are used on a daily basis to discharge water from Holderness Drain at high tide on behalf of the EA. After 2007 the EA spent approximately £900,000 on control and operational systems at its adjacent 1949 station as a short term measure to maintain their existing performance, but they are not currently used. YW only use the 1972 pumping station for sewage flows in extreme or emergency events when the sewer system is overcharged, and then only in agreement with the EA or when directed to do so by Gold Command where lives are judged to be at risk. An agreement exists between the EA and YW for YW staff to operate the station.

9.8.4 This strategy recommends increasing the capacity of Holderness Drain pumps, and recognises that the EA has developed a scheme to replace them, in association with a new flood bank adjacent to Sutton. The new pumps would go on a new area of ground, and not in its old 1949 station. This has been put on hold pending development of RHICS. As the proposals in this strategy vary from the EA’s proposals, the Agency will need to compare approaches and decide which is best and how it can be funded. The strategy also recommends that YW and EA revise the current operating arrangements to reflect the arrangements when new pumps are installed.

9.8.5 For an existing pumping regime, flood risk in each of the three reaches of the Holderness Drain is functional upon the available channel storage capacity below the location(s) where the river embankments are lowest. As the volume of flood inundation is large relative to the available channel storage capacity (i.e. the difference between antecedent storage in the channel and the first-spill channel storage capacity), minor channel reshaping provides a negligible benefit, with this analysis being confirmed by model predictions for this option. For example, in relation to the 1% AEP fluvial event, the peak inundation volume upstream of the Tickton PS is predicted to be in excess of 1,157,000 m³, in comparison to an available channel storage capacity of less than 61,000 m³.

Consultation comments

9.8.6 Comments were received to the effect that Holderness Drain should be widened and/or deepened, both above and below Tickton PS, and the extent to which a perceived lack of maintenance (removal of vegetation in particular) was exacerbating flood risk. However, as is shown above, the size of the increase would have to be substantial - almost 20-fold above Tickton alone. Also as described, it is the pumping regime that is the critical control factor.

SEA appraisal

9.8.7 As indicated in Section 7, the SEA has only undertaken limited appraisal of rejected options.
9.8.8 For this option, the SEA has concluded that negative effects would be the loss of all bankside and basal habitat during construction works and the loss of bankside or near-bankside vegetation. The positive effects include increased bankside area that could become replacement habitat and the increased area of water habitat.

9.9 Offline storage options (3, 4)

Introduction

9.9.1 Temporary floodwater storage in a designated sacrificial area, combined with creation of a preferential flowpath into this area, can reduce the overall area at risk of inundation as well as reduce flood damage costs. Model investigation of offline storage viability considered a variety of locations in the Holderness Drain (Option 3 series) and in the River Hull (Option 4 series). Many variations were analysed for example option 4 series ranged from 4a to 4g. The options described below in 9.10 and 9.11 exhibiting the highest flood mitigation potential.

9.10 Holderness Drain storage (3)

Description

9.10.1 This option aims to manage existing flood risk from the Holderness Drain upstream of the Tickton PS by design of an offline storage structure with controlled spill via a lowered section of embankment. The preferred location for the storage structure is in the bankside area north-west of where the Holderness Drain crosses under the Leven Canal. It is the lowest lying area of land in this area and is already subject to prolonged wetting.

9.10.2 This option entails the following elements:

a) The lowering of the Holderness Drain embankment over a distance of approximately 190 m from current average elevation of -0.235m AOD to -0.35m AOD (to form a spillway).

b) Provision of an offline storage basin of 1,152,000 m$^3$ capacity (storage must be provided below -0.35m AOD spill entry elevation), embanked to minimum -0.35m AOD, north of the Leven Canal beyond the west bank of the Holderness Drain (south of airfield).

c) Provision of 3 x 500 mm diameter flap valves (with -1.3m AOD invert level) for return flow to Holderness Drain, sited below the entry spillway.
9.10.3 The coordinates of the lowered bank section are between [508047, 445404] and [508017, 445220], while the suggested basin extent is between [506898, 446069] / [508100, 445740] / [507982, 444988] / [506363, 445058]. The estimated excavation requirement for the suggested extent, based on an area of 123.3 ha with 1:4 sidewall slopes to base of -1.35m AOD, is 1,316,000 m\(^3\). To achieve the minimum embankment level of -0.35m AOD, it is estimated that approximately 509 m of the basin perimeter will require raising from current ground levels by an average of 0.2m.

**Benefits**

9.10.4 The provision of an offline storage area at Tickton PS almost completely removes fluvial inundation risk in the area surrounding the Leven Canal without detrimental impact elsewhere in the catchment. An amount of residual flooding (approximately 100,000m\(^3\)) is observed upstream of Tickton PS to the north of the proposed offline storage area.

9.10.5 The main benefit of this option is reduction in the overall flood inundation volume. The modelling results have identified that the provision of the suggested offline storage area in this location will reduce the overall flood volume upstream of Tickton PS from 1,135,901m\(^3\) to 36,252m\(^3\). This is a reduction of approximately 97%, however there are little to no properties in this location which will cause difficulties with project deliverability.

**Costs**
9.10.6 The capital cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings. For these costings land acquisition has been estimated. The following is a summary of specific assumptions made in the cost estimates for all storage options:

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site material suitable for embankments - no reservoir lining required.</td>
</tr>
<tr>
<td>2</td>
<td>Site material unsuitable embankments - no lining required.</td>
</tr>
<tr>
<td>3</td>
<td>Site material suitable for embankments - lagoon base compacted in-situ.</td>
</tr>
<tr>
<td>4</td>
<td>Excavated material suitable for embankments - lagoon base constructed from imported material.</td>
</tr>
</tbody>
</table>

Table 21 - Option 3b capital cost

<table>
<thead>
<tr>
<th>Option 3b - CAPEX</th>
<th>Assumption 1</th>
<th>Assumption 2</th>
<th>Assumption 3</th>
<th>Assumption 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff costs</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
</tr>
<tr>
<td>Consultancy fees</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
</tr>
<tr>
<td>Site investigations</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Construction costs</td>
<td>£ 27,320,000</td>
<td>£ 28,940,000</td>
<td>£ 33,810,000</td>
<td>£ 61,210,000</td>
</tr>
<tr>
<td>Environ mitigation</td>
<td>£ 120,000</td>
<td>£ 120,000</td>
<td>£ 290,000</td>
<td>£ 290,000</td>
</tr>
<tr>
<td>Supervision</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Land - 130 ha</td>
<td>£ 4,820,000</td>
<td>£ 4,820,000</td>
<td>£ 4,820,000</td>
<td>£ 4,820,000</td>
</tr>
<tr>
<td><strong>SUB TOTAL</strong></td>
<td><strong>£ 33,410,000</strong></td>
<td><strong>£ 35,030,000</strong></td>
<td><strong>£ 40,070,000</strong></td>
<td><strong>£ 67,470,000</strong></td>
</tr>
<tr>
<td>60%</td>
<td>£ 20,046,000</td>
<td>£ 21,018,000</td>
<td>£ 24,042,000</td>
<td>£ 40,482,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>£ 53,456,000</strong></td>
<td><strong>£ 56,048,000</strong></td>
<td><strong>£ 64,112,000</strong></td>
<td><strong>£ 107,952,000</strong></td>
</tr>
</tbody>
</table>

9.10.7 This option was not taken forward for further economic consideration because of the large associated costs involved in lining for surface water protection zones and materials. Particularly when mitigation can be achieved at a substantially lower cost by raising embankments and adapting the pumping regime lower down the system (Option 7b + Option 1b).

Consultation comments

9.10.8 There were contrasting views about the value of off-line storage lagoons. The comments apply equally to all the Options 3 and 4 series. Farming interests and a flood action group opposed the loss of productive farmland, as it is unlikely farmers would be able to use the lagoon areas for crop production in the way unrestricted farmland can be used. The individual scheme costs did allow for land acquisition, and it is possible
land would have been leased back to previous owners, although it is recognised there is always a risk that any crops could be lost to sudden inundation.

9.10.9 The counter view was one of disappointment that schemes are not proposed to be taken forward as active strategy solutions, particularly as it means loss of opportunity to benefit wildlife and nature conservation. The basis of the costs of constructing the lagoons was also queried. Due to the unknown ground conditions at any of the locations, and as intrusive ground testing has not been undertaken, cost estimates are conservative. It is generally an Environment Agency requirement that all flood water storage lagoons in a GSP Zone 2 are lined with a layer of low permeability ($1 \times 10^{-9} \text{ m/s}$) clay. Allowance has been made to encompass four scenarios which depend on whether a liner is required, and if the material on site is appropriate for construction of embankments and the liner. A liner may also be required to meet safety standards for reservoirs, and some of the lagoon locations have recently been included in a new outer ‘Zone 3’ source protection zone. Requirements for this zone were unknown when scheme costs were prepared. Allowances were made for geotextile lining should these be required and for the importation of lining clay. Cost estimates were also based on schemes under construction in the west Hull suburbs.

9.10.10 The Yorkshire Wildlife Trust is working with the landowner in the vicinity of this proposed lagoon to manage the land for the benefit of wildlife. The proposals include breaking existing land drains to allow greater water retention.

SEA appraisal

9.10.11 As indicated in Section 7, the SEA has only undertaken limited appraisal of ‘unreasonable’ rejected options.

9.10.12 For this option, the SEA has concluded that negative effects would be the loss of productive farmland and the potential impact on cultural heritage sites. The positive effects would be seasonal habitat creation when lagoons are wet.

9.11 River Hull storage (4)

Offline storage east of Pulfin Bog (4e)

Description

9.11.1 The River Hull frequently overtops its “low level” bank in the meandering section near Arram/Eske, which has created a wetland area that partially short-circuits the meander. The eastern extent of this wetland area is contained by a raised north-south running embankment, which is predicted to be capable of containing all river water without over-topping for fluvial events of up to 100 year return period. By lowering this embankment over a limited section to create a controlled spill into a designed offline storage area, there is the potential to alleviate flood risk elsewhere- particularly in upstream tributaries (such as Mickley Dike) and the Beverley and Barmston Drain, pumped transfers from which are regulated by River Hull water levels.
9.11.2 It is proposed to lower the wetland’s easternmost embankment over a limited section to create a controlled spill into a designed offline storage area. The embankment will be lowered over a 115 m section (between coordinates [505495, 444243] and [505554, 444341]) to an elevation of 2.7m AOD.

9.11.3 The preferred location for the storage structure is to the east of the outer embankment of the wetland area, beyond the lowered section of the bank. The co-ordinates of the suggested basin extent are [505692, 444705], [507410, 443846], [507179, 443233], [505487, 444227].

9.11.4 The storage will contain floodwaters associated with fluvial peaks. The size of the storage has been calculated based on 1% AEP fluvial event, with a sensitivity analyses, performed with different spill level of the embankment. The optimised estimated storage capacity is 1,557,140 m³.

9.11.5 The required storage capacity will be contained between a base of -0.5m AOD and a crest of 2.0m AOD, by embanking to minimum 2.0m AOD an area of 97.5 ha.

9.11.6 The estimated embankment requirement is for a 4,850m of the basin perimeter to be raised from current ground levels by an average of 1.7m.

9.11.7 While the ground levels of the proposed storage and the river bed allow for gravity drainage, the equilibrium water level in this tidally-impacted reach of the River Hull is approximately 2.5m AOD. Therefore, the storage can only be drained via pumping, or else via long gravity drain to pass the water into Holderness Drain system where baseflow water levels and bed levels are much lower (<-1.5m AOD).

9.11.8 It is proposed to place a manually-operated penstock at the storage drainage location (at approximately [506318, 444545]) linked to a 750 mm diameter gravitational drainage pipe. The pipe length will be about 1300m, from the storage drainage location with upstream IL of -0.5m AOD, to discharge point into Holderness Drain (at approximately [507502,443927]), with downstream IL of -1.5m AOD. At the discharge point the pipe will be attached to a 750mm flap valve, with -1.5m AOD IL.
9.11.9 Landscaping (e.g. excavation of minor drainage channels) may be required to ensure all areas within the storage extent are drainable via the proposed gravity drainage pipe.

Benefits

9.11.10 The main benefit of this option is reduction in the overall flood inundation volume. The modelling results have identified that providing additional flood storage of 1.5 mil m$^3$ to the east of the wetland lagoon (Arram/Eske) will reduce the overall flood volume by 7%.

9.11.11 The major benefit in flood reduction for this option is in the area of the upstream tributaries where the overall flood volume reduction is 6%. The reduction in flood volumes for the Beverley and Barmston Drain area is 3%. The spreadsheet with the volume reduction results is presented in Appendix B and the maps indicating the areas with reported flood volume reduction in Annex A.

Costs

9.11.12 The capital cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings, the assumptions for the below are in Table 20. Estimates have been calculated for raising bund height to 2m AOD and 4.2m AOD.

<table>
<thead>
<tr>
<th>Option 4e: Bund height at 4.2m AOD - CAPEX</th>
<th>Assumption 1</th>
<th>Assumption 2</th>
<th>Assumption 3</th>
<th>Assumption 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff costs</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
</tr>
<tr>
<td>Consultancy fees</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
</tr>
<tr>
<td>Site investigations</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Construction costs</td>
<td>£ 14,630,000</td>
<td>£ 9,600,000</td>
<td>£ 16,100,000</td>
<td>£ 30,700,000</td>
</tr>
<tr>
<td>Enviro mitigation</td>
<td>£ 120,000</td>
<td>£ 150,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
</tr>
<tr>
<td>Supervision</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000.00</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Land</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
</tr>
<tr>
<td>SUB TOTAL</td>
<td>£ 19,500,000</td>
<td>£ 14,500,000</td>
<td>£ 21,100,000</td>
<td>£ 35,700,000</td>
</tr>
<tr>
<td>60%</td>
<td>£ 11,700,000</td>
<td>£ 8,700,000</td>
<td>£ 12,660,000</td>
<td>£ 21,420,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>£ 18,331,200</td>
<td>£ 15,699,200</td>
<td>£ 30,640,000</td>
<td>£ 63,748,800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option 4e: Bund height at 2m AOD - CAPEX</th>
<th>Assumption 1</th>
<th>Assumption 2</th>
<th>Assumption 3</th>
<th>Assumption 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff costs</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
</tr>
<tr>
<td>Consultancy fees</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
</tr>
<tr>
<td>Site investigations</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Construction costs</td>
<td>£ 6,787,000</td>
<td>£ 4,912,000</td>
<td>£ 14,150,000</td>
<td>£ 34,843,000</td>
</tr>
<tr>
<td>Enviro mitigation</td>
<td>£ 120,000</td>
<td>£ 150,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
</tr>
<tr>
<td>Supervision</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Land</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
</tr>
<tr>
<td>SUB TOTAL</td>
<td>£ 11,457,000</td>
<td>£ 9,812,000</td>
<td>£ 19,150,000</td>
<td>£ 39,843,000</td>
</tr>
<tr>
<td>60%</td>
<td>£ 6,874,200</td>
<td>£ 5,887,200</td>
<td>£ 11,490,000</td>
<td>£ 23,905,800</td>
</tr>
<tr>
<td>TOTAL</td>
<td>£ 18,331,200</td>
<td>£ 15,699,200</td>
<td>£ 30,640,000</td>
<td>£ 63,748,800</td>
</tr>
</tbody>
</table>
AOD.

Consultation comments
9.11.13 See comments in 9.10.

SEA appraisal
9.11.14 As indicated in Section 8, the SEA has only undertaken limited appraisal of ‘unreasonable’ rejected options.

9.11.15 For this option, the SEA has concluded that negative effects would be the loss of productive farmland. The positive effects would be seasonal habitat creation when lagoons are wet.

Conclusion
9.11.16 Compared to Option 4f below, which has similar costs, it is apparent that this option provides only slightly greater than half of the volumetric flood benefit for the 100 year event. Consequently this option was not taken forward for further economic assessment, and was discarded at this stage.

Offline storage south-east of Weel (4f)

Description
9.11.17 This location is the within the tidally-impacted reach of the River Hull, such that peak water levels are caused by a superposition of fluvial flows from upstream and the intrusion of tidal peaks from the River Humber. Given this, the volumetric reduction in peak inundation effected by this option will be less than the volume of water drawn off, and care must be taken to choose a spill level that provides an optimal combination of worthwhile mitigation benefit without excessive storage requirement.

9.11.18 From trials involving a range of spill elevations, it is proposed that a 160m section of the eastern bank of the River Hull (between [506697, 438421] and [506639, 438267]) is lowered to 3.2m AOD to create a spillway entry from the river into the proposed storage area.

9.11.19 Based on this spillway, modelling indicates that a storage capacity of 1,586,175 m³ is required to contain spill water generated in the period up to and including the fluvial inundation peak in the River Hull system for the critical 100 year event.

9.11.20 The preferred location for the storage structure is to the east of River Hull along the river reach south of Weel (Figure 23). The proposed storage location co-ordinates are [506745, 438526], [507625, 438995], [507897, 438670], [506840, 437909]. This covers an approximate 67.8 ha extent.

9.11.21 The required storage capacity will be contained between an existing minimum ground elevation in the area of -0.65m AOD and the 3.2m AOD elevation of the spillway entry. An additional “drowned weir” capacity will be provided by embanking the proposed storage area further to 3.5m AOD. This buffer capacity does not provide reduction in peak inundation volume/extent, but provides temporary storage to protect against tidal or secondary fluvial water level peaks which may occur after the storage area is filled to spillway level and before it begins to be drained.
The estimated embankment requirement is for 3.85m of the basin perimeter to be raised from current ground levels by an average of 2.65m.

As the equilibrium River Hull water level in the vicinity is approximately 2.5m AOD (i.e. approximately 3m above the base elevation of the proposed storage area), the storage area cannot be gravitationally drained into the River Hull. Instead, it is recommended that the storage area is manually emptied via penstock into an existing land drain to the north or east, and hence into the Holderness Drain, where equilibrium water levels are typically below -1.5m AOD.

Landscaping (e.g. excavation of minor internal drainage channels) may be required to ensure all areas within the storage extent are drainable via the proposed penstock. Further landscaping may also be required downstream of the penstock, to establish connection to one of the existing land drains to the east or north (which have estimated invert levels of approximately -0.5m AOD), and possibly to deepen the receiving drain to facilitate full drainage to -0.65m AOD.

**Benefits**

The main benefit of this option is reduction in the overall flood inundation volume. Modelling results have identified that the proposed spillway and storage area will reduce peak 1% AEP inundation volumes for the River Hull system by 8%.

The area benefiting most from the off-stream storage is around the Beverley and Barmston Drain with total reduction in 1% AEP inundation volumes of 9%. The major benefit in flood reduction for this option is in the area of the upstream tributaries where the overall flood volume reduction is 10%. The reduction in 1% AEP inundation volumes in upstream tributaries of the River Hull is relatively minor (approximately 3%). A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Figure 23.

*Figure 23 - Location of 4f storage area*
Annex A.

**Costs**

9.11.27 The capital cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings. Land may need to be acquired by Compulsory Purchase Order (CPO); assumptions for acquisition costs have been set out in Table 23.

**Table 23 - Option 4f capital cost**

<table>
<thead>
<tr>
<th>OPTION 4f – CAPEX</th>
<th>Assumption 1</th>
<th>Assumption 2</th>
<th>Assumption 3</th>
<th>Assumption 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff costs</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
<td>£ 500,000</td>
</tr>
<tr>
<td>Consultancy fees</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
</tr>
<tr>
<td>Site investigations</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Construction costs</td>
<td>£ 18,850,000</td>
<td>£ 18,030,000</td>
<td>£ 21,500,000</td>
<td>£ 32,720,000</td>
</tr>
<tr>
<td>Enviro mitigation</td>
<td>£ 120,000</td>
<td>£ 150,000</td>
<td>£ 250,000</td>
<td>£ 250,000</td>
</tr>
<tr>
<td>Supervision</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
<td>£ 200,000</td>
</tr>
<tr>
<td>Land</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
<td>£ 3,600,000</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>£ 23,720,000</td>
<td>£ 22,930,000</td>
<td>£ 26,500,000</td>
<td>£ 37,720,000</td>
</tr>
<tr>
<td>60%</td>
<td>£ 14,220,000</td>
<td>£ 13,758,000</td>
<td>£ 15,900,000</td>
<td>£ 22,632,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>£ 37,952,000</td>
<td>£ 36,688,000</td>
<td>£ 42,400,000</td>
<td>£ 60,352,000</td>
</tr>
</tbody>
</table>

Compulsory Purchase Order (CPO); assumptions for acquisition costs have been set out in Table 23.

**Table 24 - Damages option 4f**

<table>
<thead>
<tr>
<th><strong>Option 4f: Offline Storage SE of Weel</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct and indirect damages to Property</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td>Direct and indirect damages to Agriculture</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
<tr>
<td>Total PV Damage (£m)</td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
</tr>
<tr>
<td>PV Cost (£m)</td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
</tr>
</tbody>
</table>

**Economic summary**

9.11.28 The following table summarises the economic appraisal of this option:
9.11.29 The table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. It also identifies the scale of external contributions required.

Table 25 - Benefits option 4f

<table>
<thead>
<tr>
<th></th>
<th>Option 4f: Offline Storage SE of Weel</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost (£m) 2064</td>
<td>34.3</td>
</tr>
<tr>
<td>PV Benefit (£m) 2064</td>
<td>9.3</td>
</tr>
<tr>
<td>Raw PF Score</td>
<td>2%</td>
</tr>
<tr>
<td>FDGiA Contribution</td>
<td>0.8</td>
</tr>
<tr>
<td>Required Contributions</td>
<td>33.5</td>
</tr>
</tbody>
</table>

Consultation comments

9.11.30 See comments in 9.10.

SEA appraisal

9.11.31 As indicated in Section 8, the SEA has only undertaken limited appraisal of ‘unreasonable’ rejected options. For this option, the SEA has concluded that negative effects would be the loss of productive farmland and the potential impact on cultural heritage assets. The positive effects would be seasonal habitat creation when lagoons are wet.

Conclusion

9.11.32 Despite its poor economic scores this Option 4f above was taken forward for some combined modelling as hydraulically there was a chance combining storage with Option 11 series, tidal sluicing, may create much larger benefit to the system. Results of this can be found in the 9.17 Combined Options.

9.11.33 Additionally this option had a further variation 4g, which aimed to alleviate flooding in the Beverley Drain instead of the River Hull, by permitting additional pumping from the Waterside PS. Increased pumping from this PS would, in isolation, increase peak water levels in the receiving River Hull, but offline storage at Weel can be designed to offset this increase. The overall purpose and impact is therefore to mitigate flood risk in the Beverley Drain and Barmston Drain without exacerbating flood risk in the River Hull.

9.11.34 The option entailed alteration to pump operation rules for the Waterside PS to remove regulation by outlet water levels; in effect, pumps will run continuously whenever inlet water levels exceed -0.2m AOD, regardless of outlet (River Hull) water levels.

9.11.35 Further modelling of this variation showed that there is minimal difference in flood volumes between this and Option 4f. Consequently this option was discarded from further analysis.
9.12 **River Hull channel maintenance (6)**

**Description**

9.12.1 Based on recent bathymetric surveying (detailed below) of the River Hull, this option proposes improvements to channel and sections of dredging of the River Hull between the outfall into the Humber Estuary and the Hull Bridge Road bridge (just downstream of the A1035 bridge, see Figure 24). Further investigation also showed that this option would also require removal of sunken barges/vessels and other structures causing restriction to improve overall conveyance.

9.12.2 The proposed method of channel improvements would be to use a technique called Water Injection Dredging (WID). An example of a vessel that can carry out WID is shown in the figure below.

![Figure 24 - Example of WID vessel](image)

9.12.3 WID is a relatively recent approach and involves a hydrodynamic technique which is considered more cost-effective and more environmentally friendly. The process consists of injecting large volumes of water at a low pressure into the sediment through a series of nozzles on a horizontal jet bar. This loosens and fluidizes the cohesive sediment to create a layer of mudflow which is denser than the rest of the water column. This layer remains close to the bed and does not mix with, or cause disturbance to, the upper layers of the flow. This property contributes to WID being considered more environmentally sound, as the aquatic ecosystem is not disturbed by silt, unlike more traditional methods of dredging (i.e. agitation). Being a low pressure system, it also means there is less likely to be damage to buried archaeological artefacts.

9.12.4 Once the fluidized silt layer is formed, this method relies on gravity-driven density currents and frictional force to transport this mobilised silt to a deeper area for deposition. By relying on a natural process this technique is considered cost-effective due to no resource needed for transportation or deposition of excavated material. WID is also understood to be better than conventional dredging approaches because dredged material does not leave its natural environment and stays within the aquatic regime.
Additionally the mudflow does not interfere with upper layers in the water column which could disturb the ecosystem, and the CO₂ footprint per m³ of dredged sediment is considerably lower than traditional methods.

9.12.5 However, although having multiple benefits, WID can only be feasible in site with specific characteristics:

- Sediment to be dredged cannot be too cohesive
- Sediment cannot be polluted
- Gradient of channel needs to be sufficiently steep to allow gravity induced flow
- A deeper area downstream is required to transport mobilised silt
- The flow regime must maintain and stabilise a high concentration in the mudflow
- Length to be dredged is not too long so that momentum isn’t lost leading to deposition of sediment too soon
- Appropriate machinery can access the area for dredging.

9.12.6 Looking at the above characteristics WID may potentially be appropriate for the lower stretch of the River Hull. From Ennerdale bridges to Stoneferry the flow regime is at is fastest and would support the fluidized sediment layer, with some minor channel re-profiling it would be possible to include the narrowed section of the River north of the Ennerdale Bridge also. However if this stretch becomes too fast then the interface between this layer and the upper water column may be broken down causing turbulent mixing across all layers. Contrastingly, between Beverley Beck and Hull Bridge, the flow could be too slow and unable to sustain the transport of sediment to the mouth of the river, investigations will need to take place once vessels are removed to assess whether dredging using WID then becomes feasible.

9.12.7 Further investigation post modelling also showed that this option would also require removal of sunken barges/vessels and other structures to improve overall conveyance.

Benefits

9.12.8 This option is predicted to reduce peak 1% AEP inundation volume in the River Hull system by 4%. However, the baseline ("do minimum") case is based on 1999 bathymetric survey data, consistent with previous ISIS-TULFOW modelling, with the predicted 4% reduction associated with this option being relative to 1999 bathymetry. Recent 2014 river bathymetry surveying, undertaken as a component of this project, identified barges and other obstacles not accounted for in 1999 surveying. If this option is instead assessed against predicted inundation based on 2014 bathymetry, it is estimated to reduce peak 1% AEP inundation volumes in the River Hull system by 10%.

9.12.9 For the 1% AEP critical event, this option is capable of producing peak water level reductions of up to 97 mm relative to the baseline within the River Hull. While this reduction in peak water level is relatively minor, dredging also decreases predicted water levels at any point in time throughout a given simulation. This overall reduction in water level has a significant impact upon pumped transfers from the Beverley and Barmston Drain. For example, the peak water level at the Wilholme PS outlets is predicted to be reduced by only 7 mm relative to the baseline, but reductions of non-peak water levels of up to 140 mm are predicted relative to the baseline (or 258 mm relative to 2014 bathymetry), see Figure 25 below. These more substantial reductions in non-peak water levels at the pump outlet locations permits a higher transfer of water from the Beverley and Barmston (and its tributaries) into the River Hull. This increased pumped transfer consequently reduces flood inundation from the Beverley and Barmston Drain, and is also responsible for partially masking the benefit of dredging upon the River Hull itself. The impact of dredging on peak flooding is thus secondary,
and although it should be considered as a part of the flood management strategy for this area it cannot provide a solution alone. While the flood mitigation benefits of dredging are relatively small in comparison to some other options that are considered in this study, dredging also provides other benefits satisfying the overall management strategy objectives for the River Hull system, including improved navigation. A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.
WID considerations

9.12.10 WID has mainly been used in estuarine/tidal river areas and to a lesser extent on inland systems. Examples of its use for tidal river systems are the River Severn at Gloucester (tidally influenced) and the tidal River Bure, Great Yarmouth, Norfolk. For any inland river system there are restrictions on dredging imposed by the EA, which are summarised in Table 26 below and with applicability to WID outlined as well. Most of these restrictions are not largely applicable to WID because they account for dredging methods which remove sediment from the channel and disposal/distribution on banks or nearby agricultural land.

Table 26 - Restrictions on dredging with assessment for WID on River Hull

<table>
<thead>
<tr>
<th>Restriction</th>
<th>Description</th>
<th>Applicable for WID?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legally protected areas</td>
<td>SACs, SPAs, SSSIs</td>
<td>Applicable</td>
</tr>
<tr>
<td>Environmental stewardship</td>
<td>Protection of land</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Tree preservation order</td>
<td></td>
<td>Not applicable</td>
</tr>
<tr>
<td>Marginal vegetation</td>
<td>Should be retained or removed in phases</td>
<td>Applicable – As little disturbance as possible to the marginal vegetation from the WID vessel</td>
</tr>
<tr>
<td>Bird Breeding</td>
<td>Dredging should not take place during bird nesting season</td>
<td>Applicable</td>
</tr>
</tbody>
</table>

Figure 25 – Water levels at Wilholme PS for dredging option
<table>
<thead>
<tr>
<th>Protected species</th>
<th>Water vole, badger, great crested newt</th>
<th>Appropriate mitigation and appraisal of habitat before dredging occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish spawning</td>
<td>Dredging not to occur in season</td>
<td>Dredging should occur between November and January (but see below)</td>
</tr>
<tr>
<td>Invertebrates and fish</td>
<td>Removed species should be allowed to return to river</td>
<td>Applicable – will be disturbed but not removed from channel. Avoid lamprey migration period (November – May)</td>
</tr>
<tr>
<td>Pollution</td>
<td>No polluted sediment should be moved elsewhere</td>
<td>Applicable, sediment to be analysed before dredging occurs</td>
</tr>
<tr>
<td>Hazardous material</td>
<td>No material which could be dangerous to other locations can be moved or must be treated first.</td>
<td>Applicable – sediment will be chemically analysed before dredging occurs</td>
</tr>
<tr>
<td>Non-hazardous material</td>
<td>May be dangerous to ground water concentrations</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Controlled weeds</td>
<td>Japanese knotweed/ Giant hogweed to be contained</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Nitrate vulnerable zones</td>
<td>Dredgings to be spread across agriculture only if contain enough nitrate</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Dewatering</td>
<td>Raising/lowering of water levels to be carried out with care</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Archaeology</td>
<td>Precautions if archaeological area</td>
<td>Applicable – potential for unknown artefacts</td>
</tr>
<tr>
<td>Utility services</td>
<td>Care to be taken around services.</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

9.12.11 When considering dredging approaches the waste hierarchy may come into play. Outlined in Figure 26 this describes the priority response to dredged material. The best possible option here is prevention of dredged material, which is the case for WID. Along with this the EA and British Waterways (now Canal and Rivers Trust) have an obligation, under the Habitat Regulation 1994, to further conserve and enhance flora and fauna in SSSIs, SPAs and SACs.

9.12.12 If these areas fall within the area to be dredged, precautions may have to occur. This obligation also highlights the necessity for dredging to take place between particular months, so not to disturb nesting birds and spawning sites etc. Impact on species of fish, protected species such as Lamprey and reed bed habitat will also need to be taken into account. The Strategy Environmental Assessment and Habitat Regulations Assessment look closer at the environmental issues regarding WID and boat removal, a summary regarding this option can be found in SEA Appraisal section below.

9.12.13 Records of pollution levels affecting the channel needs to be assessed to determine if the sediment is contaminated and inappropriate to dredge. Sampling of the sediment is an identified part of the WID process and any areas with contaminated material will not be touched by WID. The EA has identified the following locations for historic pollution:
9.12.14 In some locations where WID has been carried out, it was found that tidal influence on sediment was much greater than the influence of WID. Also the denser fluid layer of suspended sediment will flow naturally under gravitational and frictional force. This layer will eventually merge back into the natural sediment flow in the river and be deposited where sediment from the Hull naturally would settle. Additionally if there are areas in the channel where the sediment is unwanted, flow channels can be created to carry sediment away from these areas. The involvement of these natural processes in WID minimises the impact of the Humber Estuary SSSI.

9.12.15 Before WID takes place various characteristics of the river (contaminated material, need for flow channels, particle size, existing currents, etc.) will need to be investigated to deduce if the process is possible and worthwhile. Figure 27 below shows the assessment process. As well as this, a strategy to minimise impact to the surrounding environment and river ecology will have to be devised. If areas of this stretch of the River Hull are suitable for WID, this could be a considerably viable and effective option for increasing flood capacity in the channel. The diagram below shows the pre-assessment stages needed before proceeding with WID. Appropriate consents will need to be obtained from the Marine Management Organisation, the Environment Agency.
and Natural England. They will be consulted on the testing and assessment process.

**Costs**

9.12.16 The capital cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings. The following is a summary of the assumption made in the cost estimates:

Table 27 - Option 6 capital cost

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredging</td>
<td>£244,660</td>
</tr>
<tr>
<td>Environmental Assessment and monitoring</td>
<td>£175,000</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td><strong>£419,660</strong></td>
</tr>
<tr>
<td>60% optimum bias</td>
<td>£252,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>£672,000</strong></td>
</tr>
</tbody>
</table>

9.12.17 The following summarises a possible scenario for the operational cost which was used for the economic assessments:

Table 28 - Option 6 operational cost (annual equivalent)

<table>
<thead>
<tr>
<th>Description</th>
<th>Frequency</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank maintenance and vegetation clearance</td>
<td>Annually</td>
<td>£30,000</td>
</tr>
<tr>
<td>River channel survey</td>
<td>Every 5 years</td>
<td>£30,000</td>
</tr>
<tr>
<td>Re dredging</td>
<td>Every 10 years</td>
<td>£595,000</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td></td>
<td><strong>£95,500</strong></td>
</tr>
<tr>
<td>60% optimum bias</td>
<td>Equivalent per annum</td>
<td>£57,300</td>
</tr>
<tr>
<td>Operational cost of existing assets in catchment</td>
<td>Annually</td>
<td>£1,090,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>£1,242,800</strong></td>
</tr>
</tbody>
</table>

**Economic summary**

9.12.18 Alternative sub-options within this context include a reduced frequency of dredging (Option 6b), which would reduce the PV Costs to £1.2m that would increase the BCR

Table 29 - Option 6 economics

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct and indirect damages to Property</strong></td>
<td></td>
</tr>
<tr>
<td>PV Damage (£m)</td>
<td>167.7</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>Direct and indirect damages to Agriculture</strong></td>
<td></td>
</tr>
<tr>
<td>PV Damage (£m)</td>
<td>154.7</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
<tr>
<td>Total PV Damage (£m)</td>
<td>322.4</td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
<td>1.9</td>
</tr>
<tr>
<td>PV Cost (£m)</td>
<td>2.0</td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
<td>0.95</td>
</tr>
</tbody>
</table>
9.12.19 A second alternative sub-option (Option 6c) utilises the same frequency as Option 6 but brings in a revenue stream to pay for the capital costs of frequent survey and dredging. The table above summarises the economic appraisal of this option.

9.12.20 Sources of the revenue could include, for example, the setting up of a new Navigation Authority role and charging for use of moorings upstream of the City of Hull. An estimated income of £100k per year provides sufficient income to cover the cost of implementing the frequent capital investment based on a quote received during the project. Analysis indicates that income of approximately £63,750 would be sufficient to result in a break even situation in cash terms, however, an income of £66,900 would be sufficient to break even in PV terms.

Funding and contributions

9.12.21 The following table shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. It also identifies the scale of contributions required.

<table>
<thead>
<tr>
<th>Option 6: Dredging of River Hull</th>
<th>Option 6b: Reduced Frequency of Dredging</th>
<th>Option 6: With revenue stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost (£m) 2064</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>PV Benefit (£m) 2064</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Raw PF Score</td>
<td>7%</td>
<td>12%</td>
</tr>
<tr>
<td>FDGiA Contribution</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Required Contributions</td>
<td>1.5</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjusted PF Score = 101%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contributions = 1.5</td>
</tr>
</tbody>
</table>

Alternative dredging solutions

9.12.22 Whilst WID remains the preferred dredging technique, because it is a low pressure and less intrusive system that relies on the natural characteristics of the river, its likely success will depend to a significant extent on an analysis of sediments and obtaining the necessary consents following that analysis. For comparison purposes alternative
dredging techniques have been costed, and these are shown in the table below.

9.12.23 As can be seen, the cost differentials are very significant, and would have a bearing on the quantity of material that could be removed for any fixed budget (e.g. if suction dredging was to be used only 5% of the sediment volume of WID dredging could be removed for the same cost). Modelling of options affecting the river all assume a dredge back to at least a 1999 profile (some amendments made in 2007). Modelled benefits will not be met if this cannot be achieved. In addition, non-WID techniques are all more intrusive, with greater potential to harm wildlife or damage archaeological remains.

Sunken vessel removal

9.12.24 The 2014 survey identified up to twenty sunken or abandoned vessels that cause restrictions to flow and capacity within the river, especially as there is frequently sediment build-up between vessels and the river bank. These vessels almost entirely precede in the Beverley beck to Hull Bridge, Tickton. Most vessels appear to be relatively intact, but some have been reduced to skeletons owing to their construction and length of time in the river. It must be emphasised that boat removal is not proposed for aesthetic reasons — they have a measurable effect on the channel. The benefits of their removal, along with other channel restrictions, is described along with channel improvements. Many river bank structures also contribute to sediment build-up, and the majority are unconsented. They will also need to be addressed.

9.12.25 Supplementary surveys have been carried out which catalogue the vessels in more detail by habitat potential, flotation, size and blockage factor. Internal examination of vessels revealed no evidence of otters, but there was evidence which appears to show they are used for resting. Licenses and consents will need to be sought from the likes of the EA, MMO and various other bodies. Along with works to remove them ERYC will also seek to find owners of the vessels in the hope they may refloat or remove restriction themselves.

Consultation comments

9.12.26 This component was received the most responses of all in the strategy during consultation.

9.12.27 Dredging the river and removal of sunken vessels was supported by a large majority of consultees. Most of which commented that this was a known and obvious contributor to flood risk and that removal of the boats would have the wider social and leisure benefits to the River itself and the area in Beverley.

9.12.28 However, it also attracted the most significant concerns, particularly over potential impacts on certain species, such as lamprey and otters, and on bankside vegetation, which supports bird populations and provides refuge for fish. Relatively little is known about lamprey, a protected species in the R. Hull, although they are suspected of being in the river throughout all life stages. Otters have been seen regularly, especially near sunken vessels where fish are known to congregate.

9.12.29 Anglers have expressed concerns over both aspects of this option on a nationally renowned coarse fishery, as slack and shallow water provide shelter for fish, particularly from predators. Loss of marginal vegetation (mainly reedbeds) was a concern for several consultees owing to their value as habitat. Concern was also expressed about the potential impacts on water levels on riverside SSSIs and dredged sediment impact on the Humber’s habitat designations. Concern has also been expressed about potential impacts on any hidden archaeological remains, and how they might be assessed and then preserved.
SEA appraisal and mitigation

9.12.30 The SEA reports that the 2014 survey results show that riparian reedbeds have encroached by up to 4m since the last detailed survey was undertaken in 1992, thus reducing the width of the river channel and encouraging sedimentation. A decline in river traffic has accelerated this, as previously turbulence from propellers was utilised as an informal dredge mechanism. Water injection dredging mobilises sediment in a similar way to river traffic. Dredging and removal of riparian vegetation is proposed for this watercourse from the Humber to Ennerdale Bridge only.

9.12.31 As part of the boat removal process, compensatory habitat will be created for fish, otter, water vole and nesting birds. The foreshore between the two embankments from Beverley to Hull Bridge is considered wide enough to include marginal habitat, especially on the right bank. This marginal habitat will improve the geomorphological complexity of the River Hull which will in turn provide a greater variety in habitat. As the HRA has scoped in potential impacts on river lamprey, it will be necessary to avoid the specie’s migration periods, which vessel removal and dredging should preferably only take place between June and September.

9.12.32 Removal of reedbed will be selective, mainly from where it has grown out into the channel, such as between sunken vessels and the natural river bank, and will be off-set by the creation of new reedbeds by transplanting where the foreshore allows (the space between river channel and embankments). At the project level, detailed design supported by more targeted habitat survey could determine suitable locations for this mitigation measure. Long term effects of water quality degradation due to lack of riparian buffer strip are unlikely to be great due to only encroaching sections of reed beds being removed.

9.12.33 The SEA indicates there are unlikely to be any direct effects (either physical or visual) on identified designated cultural heritage assets, but there are expected to be a large number of non-designated assets (both currently known and unknown) within and adjacent to the river channel. An appropriate level of research and field survey, initially involving a detailed desk-based assessment and walkover inspection along the corridor, but possibly also including some localised intrusive investigations to characterise the resource, will need to be undertaken to ensure that all potential assets within the development footprint have been identified at early stage.

9.12.34 Detailed consultation will be needed with the Humber Archaeology Partnership. Other surveys undertaken as part of this option, e.g. hydrological and profile surveys, may also help to identify assets currently hidden below the waterline. While many assets will have been removed by previous flood schemes, others are likely to be scattered throughout the length of the proposed works, and there are expected to be a concentration in the lower reaches of the river as it passes through Hull Old Town. Results should be fed into the design process, so that cultural heritage issues are addressed from an early stage of scheme development. Further investigations and surveys may be required to adequately record and/or remove identified assets prior to scheme implementation, as there may not necessarily be the potential for preserving identified historic structures in situ.

9.12.35 The design of the proposed option means that there are unlikely to be any direct in-situ cultural heritage enhancements resulting from scheme implementation, although associated works, such as publishing the results of any surveys and assessments, should be used to enhance the general understanding and appreciation of the history of the River Hull corridor.
9.12.36 Both vessel removal and water injection dredging will cause disturbance to river bed sediments. Therefore, it is necessary to undertake a sediment sampling, testing and analysis programme to determine if there are any contaminants in them. It will also help determine whether the sediments are suitable for WID treatment. This programme will require the consent of the Marine Management Organisation and the Environment Agency. Should it be necessary a silt screen or curtain could be deployed towards the river mouth to trap contaminated sediments to prevent them entering the Humber, allowing them to be recovered or treated. However, it is more likely that another dredging technique would need to be employed if contaminants above particular thresholds are likely to be mobilised.

9.13 Embankment raising (7)

Introduction

9.13.1 Where flooding is caused by overtopping of a limited length of lower-than-average elevation bank, raising these low bank sections may be a feasible method for reducing flood risk. However, this option has two basic limitations:

a) If a given section of bank is raised to prevent flooding, the resulting new higher in-channel peak water levels may induce or worsen flooding elsewhere upstream or downstream; it is therefore important to assess the catchment-wide impact of even a very limited section of bank raising.

b) If the volume of existing flooding at a given location is substantially larger than the bank-full capacity of the local reach, the required amount of bank raising to prevent flooding will be large, and may extend much beyond the original extent of bank overtopping. Offline storage is more likely to be effective than bank raising in such a scenario.

9.13.2 This option examined the requirements, and flood risk consequences (in terms of decreased local flooding and potentially increased flooding elsewhere), of raising the following sections of embankment sufficiently to prevent local bank overtopping:

b) Holderness Drain, downstream of Great Culvert PS
c) Holderness Drain, between Tickton PS and Great Culvert PS
d) Holderness Drain, upstream of Tickton PS
e) Monk Dyke
f) Monk Dyke plus Holderness Drain downstream of Great Culvert PS
g) Arram Beck (tributary of the River Hull)
h) Mickley Dyke and Roam Dyke
i) Beverley and Barmston Drain, south of Beverley Beck
j) Beverley and Barmston Drain, between Beverley Beck and Arram Beck
k) Beverley and Barmston Drain, between Arram Beck and Lock Hill
l) As for (j), including bank raising on Watton Beck.

9.13.3 Of these variations, only Options 7b and 7i were demonstrated to be capable of providing flood risk mitigation without consequence elsewhere and with acceptably low height and length of required bank raising.

9.13.4 The following conclusion can be drawn from the outcome of this modelling:

a) The large volume of flood inundation from the Holderness Drain upstream of the Great Culvert PS means that very large amounts of embankment raising are needed to prevent inundation. The resulting increase in peak water levels detrimentally
increases peak water levels elsewhere in the Holderness Drain, resulting in substantial detriment (i.e. increase in inundation volume/extent). Likewise, embankment raising to protect Monk Dike from overtopping detrimentally increases inundation from the Holderness Drain below Great Culvert PS.

b) Embankment of the Holderness Drain below Great Culvert PS removes fluvial inundation risk in the Bransholme area without detrimental impact elsewhere, and so should therefore be progressed for economic evaluation.

c) The situation in the Beverley and Barmston Drain is similar, with embankment

<table>
<thead>
<tr>
<th>Table 32 - Preliminary assessment of feasibility of embankment raising</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raised Bank Section</strong></td>
</tr>
<tr>
<td><strong>Holderness Drain, downstream of Great Culvert PS</strong></td>
</tr>
<tr>
<td>Holderness Drain, Tickton PS to Great Culvert PS</td>
</tr>
<tr>
<td>Holderness Drain, upstream of Tickton PS</td>
</tr>
<tr>
<td>Monk Dyke (HD tributary)</td>
</tr>
<tr>
<td>Downstream of Great Culvert PS + Monk Dyke</td>
</tr>
<tr>
<td>Arram Beck (Hull tributary)</td>
</tr>
<tr>
<td>Mickley Dyke and Eastern Roam</td>
</tr>
<tr>
<td>Beverley and Barmston (south of Beverley Beck)</td>
</tr>
<tr>
<td>Beverley and Barmston (Arram Beck to Beverley Beck)</td>
</tr>
<tr>
<td>Beverley and Barmston (Lock Hill to Arram Beck)</td>
</tr>
<tr>
<td>Beverley and Barmston (Lock Hill to Arram Beck, incl Watton)</td>
</tr>
</tbody>
</table>
raising in one section tending to detrimentally impact flood risk elsewhere, with embanking of the section south of Beverley Beck being the only option that reduces local flood inundation without detriment elsewhere.

9.13.5 The progressed options are hereafter referred to as follows:

a) Option 7b: Embanking of the Holderness Drain downstream of the Great Culvert PS  
b) Option 7i: Embanking of the Beverley and Barmston Drain south of Beverley Beck.

9.13.6 As indicated in Section 7, the SEA has only undertaken limited appraisal of rejected options. For this option, the SEA has concluded that negative effects would be that embankments could be a possible long-term barrier to some species and disruption to wildlife during construction. Offsetting from current alignment could create new habitat opportunities as compensation. More analysis is provided below for the two embankment-raising options that are proposed to be progressed.

**Embankments downstream of Great Culvert PS (7b)**

**Description**

9.13.7 Figure 28 below indicates the sections that will be embanked for this option. On the Holderness Drain between Great Culvert and East Hull PS and on Ganstead drain a stretch from near its confluence with the Holderness drain eastwards.
9.13.8 The Holderness Drain overtops its banks in locations with a lower than average crest elevation. This option aims to directly alleviate flood risk by preventing this overtopping, noting that this will result in higher peak water levels in the impacted sections of the drain.

9.13.9 It is proposed to raise the embankment of the Holderness Drain downstream of Great Culvert pumping station to reduce flooding, particularly in the area of Bransholme. Approximately 1957m of bank requires raising on either bank to a minimum level of 1.9m AOD. Bank raising relates to discontinuous sections between coordinates [513559,433072] and [511453,435551]. The average height of required embankment raising is approximately 0.2m.

9.13.10 As the Ganstead Drain freely drains into the Holderness Drain in the impacted section, increased water levels will also impact upon flood risk for this tributary drain. The embankments of the Ganstead Drain must therefore also be raised to a minimum of 2.05m AOD. This entails raising approximately 1731m of embankment by an average of 0.3m, relating to discontinuous sections between coordinates [514743,433741] and [513839,433410].

Benefits

9.13.11 The raising of the embankments on the Holderness Drain below Great Culvert PS removes fluvial inundation risk in the Bransholme area and Ganstead Drain catchment, with some minor predicted detriment in the Foredyke Stream and its tributaries – particularly between the Lambwath Stream and Kelwell Drain. Volumetrically, this option reduces the peak 1% AEP inundation volume for the Holderness Drain system by only 3%. However, the bulk of this reduction occurs in high-value urban areas.

9.13.12 A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.

Costs

9.13.13 The cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings. The following is a summary of the assumption made in the cost estimates:

<table>
<thead>
<tr>
<th>Table 33 - Option 7b capital cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 7b – CAPEX</strong></td>
</tr>
<tr>
<td>Staff costs</td>
</tr>
<tr>
<td>Consultancy fees</td>
</tr>
<tr>
<td>Site investigations</td>
</tr>
<tr>
<td>Construction costs</td>
</tr>
<tr>
<td>Environmental mitigation</td>
</tr>
<tr>
<td>Supervision</td>
</tr>
<tr>
<td>Land</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
</tr>
<tr>
<td><strong>60%</strong></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
</tbody>
</table>
9.13.14 Provision of material, and construction costs, associated with raising approx. 1967m of bank to a minimum level of 1.9m AOD. Land may need to be acquired by Compulsory Purchase Order (CPO). No allowance is made for this at this stage.

Economic summary

9.13.15 The following table summarises the economic appraisal of this option.

Funding and contributions

9.13.16 The following table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. It also identifies the scale of external contributions required.

9.13.17 It should be noted that the true benefit of this option is in the region of £80m relative to the Baseline. However, because of the agreed approach to the apportionment of benefits within the affected areas, only £0.4m of PV Benefit is available. Whilst this generates a low benefit to cost ratio within the PF Calculator, this is more than offset by the OM2 benefits generated by reducing the flood risk classification of 714 properties. This reduction in risk to properties is what is driving the high Raw PF score in this case.

Consultation comments

9.13.18 There was a concern that the proposed new embankments could prevent water from lateral drains entering Holderness Drain, causing more waterlogging, due to higher
water levels in the drain. It is recognised water levels as maintained are artificially high, and the proposal seeks to lower them. It will be necessary to assess all control structures at drain junctions to ensure there is no adverse backflow.

9.13.19 Improvements to the two retained pumping station were considered vital. As East Hull pumping station is jointly owned, but currently operated by Yorkshire Water, YW and the EA are to consider new joint redesign and operational arrangements that would allow for dual use (pumping of sewage for Humbercare, and pumping Holderness Drain into the Humber when drain levels are high and the drain is tidally locked). At present joint simultaneous use by YW’s pumps can cause damage.

9.13.20 Some consultees felt Tickton PS should not be decommissioned until it was shown that the new weir arrangement there adequate and that the upgrade of the two lower pumping stations had been completed and tested. The exact sequence of events has yet to be determined, but although considered to be unnecessary, this option could be investigated further as part of the design process.

**SEA appraisal, mitigation and enhancement**

9.13.21 The SEA identifies that raising of the Holderness Drain embankments may create localised visual impacts, so mitigation measures should include a more detailed consideration of embankment profile i.e. where possible side slope gradients could be less steep and of variable gradient to create more natural profiles that integrate better with the generally flatter landscape of the locality. A vegetation survey at the detailed design stage will also enable greater consideration of retaining such features. Planting of flood defence embankments is not considered to be appropriate due to necessary management measures.

9.13.22 The raising of the Holderness Drain embankments will have a direct physical and visual effect on the Swine Castle Hill Scheduled Monument, which lies on the immediate east side of the drain. An appropriate level of desk-based research, together with a topographical survey of the castle site, will need to be undertaken to ensure that all potential impacts are identified at early stage. Construction is likely to require Scheduled Monument Consent, and design options will need to be discussed and agreed with Heritage England. A detailed desk-based assessment and walkover survey, perhaps also with localised intrusive investigations, will also be undertaken across the whole development footprint, to ensure that non-designated cultural heritage assets (both currently known and unknown) are identified. Consultation will need to be held with the Humber Archaeological Partnership as part of this process. Results from the surveys will be fed into the design process, so that cultural heritage impacts issues are addressed from an early stage of scheme development.

9.13.23 Sympathetic design will also be required to minimise any direct or visual impacts on the Scheduled Monument and the listed structures adjacent to the East Hull Pumping Station. Depending on other specific impacts, further investigations and surveys may be required to adequately record and if necessary remove identified assets prior to scheme implementation, although it is assumed that much of the existing 19th century drain-side infrastructure will be preserved.

9.13.24 The potential adverse effects identified at the construction stage can be mitigated through careful site management and site protocols. Stockpiles and aggregates should be sealed and stored away from flow paths into watercourses. Reinforcing turf mats can be used along the embankments to ensure that topsoil is not eroded before it has vegetated. It is recommended that a CEMP be prepared in advance of any works.
9.13.25 The SEA identifies potential opportunities to enhance flora, fauna and biodiversity by increasing habitat connectivity through creation of wet woodland strips between embankments and watercourses. Education of landowners on sensitive land management practices to promote ecologically enhanced hydrological management could take place as part of a wider River Basin Management Plan programme.

9.13.26 Landscape enhancement opportunities are limited. Consideration, in consultation and agreement with landowners, could be given to of offsite planting areas to help integrate the raised embankments into the existing landscape and offer additional visual screening at selected locations; project level landscape and visual impact assessment will assist this process. To supplement the suggested biodiversity enhancement measures, wet woodland could be created adjacent to the Holderness Drain at selected locations.

9.13.27 There is some potential for the enhancement of the cultural heritage resource with this option, for example repairing or conserving the existing 19th century drain-side infrastructure and increasing public awareness and appreciation of the history of the land River Hull corridor (e.g. through information panels, leaflets etc.), particularly its land drainage history, where the proposed works coincide with public footpaths and other rights of way.

**Embankments on Beverley and Barmston Drain and tributaries**

**Description**

9.13.28 Figure 29 below indicates the main sections proposed to be impacted by this option. On Beverley and Barmston Drain in isolated spots between Beverley Beck and the River Hull confluence, and Western/Fox Drain to its confluence with the Beverley and Barmston Drain.

Figure 29 - Proposed banks for option 7i

- n Drain, along with its Western Drain tributary overtops its banks in locations with a
lower than average crest elevation. This option aims to directly alleviate flood risk by preventing this overtopping, noting that this will result in higher peak water levels in the impacted sections of the drain.

9.13.30 Approximately 721m of the Beverley and Barmston Drain bank requires raising on either bank to a minimum level of 1.45m AOD. Bank raising relates to discontinuous sections of bank between coordinates [507202, 434897] and [505884, 438870]. The average height of required embankment raising is approximately 0.25m. Approximately 3231m of the Western Drain bank requires raising on either bank to a minimum level of 2.0m AOD. Bank raising relates to a largely contiguous section of both banks between coordinates [505919, 435573] and the confluence point with the Beverley and Barmston Drain. The average height of required embankment raising is approximately 1m. The existing flap valve discharge from the Western Drain into the Beverley and Barmston Drain is inadequate to conduct high flows during extreme events without causing flooding. It is therefore proposed that a 2m wide high flow weir with crest level of 1.4m AOD is constructed at the confluence point.

9.13.31 It should be noted that the fluvial model used for these results does not have culverts through the A1079, as well as surrounding roads. A comparison of the impact of these culverts on 1% AEP baseline flooding is shown in Fig 30 and 31. This suggests that the impact of ignoring these culverts upon predicted fluvial-only inundation extents is likely to be minor, with the inundation extent created by this flow, not predicted to extend beyond (south of) the Counter Dike, so there is no impact on the Orchard Park estate. The integrated model discussed later, includes representation of the road culverts for the baseline and full option.

Benefits

9.13.32 The raising of the embankments proposed by this option removes fluvial inundation risk in the area south of Beverley, with some very minor detriment predicted further upstream. Predicted detriment may be alleviated by combination with another solution option (e.g. Option 11).

9.13.33 Volumetrically, this option reduces the peak 1% AEP inundation volume for the River Hull system by only 2%. The economic viability of this option therefore depends upon the relative value of land/buildings it protects from inundation.
9.13.34 A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.

**Costs**

9.13.35 The capital cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings. Provision of material and construction costs, associated with raising approximately 573m of bank to a minimum level of 1.4m AOD. The following is a summary of the assumption made in the cost estimates:

<table>
<thead>
<tr>
<th>Table 36 - Option 7i capital cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 7i - CAPEX</strong></td>
</tr>
<tr>
<td>Staff costs</td>
</tr>
<tr>
<td>Consultancy fees</td>
</tr>
<tr>
<td>Site investigations</td>
</tr>
<tr>
<td>Construction costs</td>
</tr>
<tr>
<td>Environmental mitigation</td>
</tr>
<tr>
<td>Supervision</td>
</tr>
<tr>
<td>Land</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
</tr>
</tbody>
</table>

60% £ 1,944,000

**TOTAL** £ 5,184,000

<table>
<thead>
<tr>
<th>Table 37 - Damages for option 7i</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 7i: Beverley and Barmston Drain Embankment Raising</strong></td>
</tr>
<tr>
<td>Direct and indirect damages to Property</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td>Direct and indirect damages to Agriculture</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
<tr>
<td>Total PV Damage (£m)</td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
</tr>
<tr>
<td>PV Cost (£m)</td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
</tr>
</tbody>
</table>

9.13.36 The following table summarises the economic appraisal of this option.

**Economic summary**

9.13.37 The following table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), i

<table>
<thead>
<tr>
<th>Table 38 - Benefits option 7i</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 7i: Beverley and Barmston Drain Embankment Raising</strong></td>
</tr>
<tr>
<td>PV Cost (£m) 2064</td>
</tr>
<tr>
<td>PV Benefit (£m) 2064</td>
</tr>
<tr>
<td>Raw PF Score</td>
</tr>
<tr>
<td>FDGiA Contribution</td>
</tr>
<tr>
<td>Required Contributions</td>
</tr>
</tbody>
</table>
cates the following potential FDGiA contributions for this option. It also identifies the scale of external contributions required, for this option a fair amount of external funding would be required however the option does benefit numerous businesses in the area so there maybe potential to satisfy that requirement in terms of

Consultation comments

9.13.38 There were limited public comments on this aspect of the Beverley and Barmston Drain’s flood risk issues (most related to sections north and south of Dunswell). There were concerns vegetation maintenance was not adequate, and that adequate controls were in place to prevent backflow into Western and Fox Drains. The proposals include a new high level weir at the junction of the two larger drains to prevent this.

SEA appraisal, mitigation and enhancement

9.13.39 As with Holderness Drain, new embankments here may create localised visual impacts, so embankment profile needs careful consideration, i.e. where possible side slope gradients could be less steep and of variable gradient to create more natural profiles that integrate better with the generally flatter landscape of the locality. A vegetation survey at the detailed design stage will help what can be kept or enhanced, and what should be removed to reduce flood risk (e.g. at the location of the new weir). Planting of flood defence embankments is not considered to be appropriate due to necessary management measures.

9.13.40 There will be no direct impacts on any designated cultural heritage assets as a result of this option, although there are likely to be some (both physical and visual) on a number of non-designated assets (both currently known and unknown). An appropriate level of research and field survey, initially involving a detailed desk-based assessment and walkover survey but possibly also including some localised intrusive investigations, will need to be undertaken to ensure that all potential assets within the development footprint have been identified at early stage. Liaison with the Humber Archaeology Partnership will assist. Survey results can be fed into the design process. On site and considerate contractor protocols can be used to protect soils.

9.13.41 The SEA considers that there is the opportunity, in conjunction with landscape enhancement measures, to increase habitat connectivity through creation of wet woodland strips between embankments and watercourse. In consultation and agreement with landowners, offsite planting areas may be considered to enable further enhancement planting to take place. Such planting could help integrate the proposed sections of raised embankments into the existing landscape and offer additional visual screening at selected locations; a project level landscape and visual impact assessment will assist this process. To supplement the suggested biodiversity enhancement measures, wet woodland could be created adjacent to the drains at selected locations. Consideration could be given to extending the rights of way network, which is limited and piecemeal in this area.

9.14 Upland natural attenuation (8)

Description

9.14.1 Instead of an approach to flood alleviation which is focussed on the conveyance of water through the catchment by increasing channel capacity and efficiency, Natural Flood Management (NFM) aims to delay the flow of water through the basin by means of attenuation and infiltration of surface water. NFM is employed upstream of towns and villages to reduce and slow peak flow, and involves reverting from modern farming practices.
9.14.2 Modern farming has resulted in altering the topography of fields, diverting drainage ditches and reducing space assigned to hedgerows and woodland. These practices contribute to surface water reaching water courses sooner and sedimentation in channel. A study of farms in the Netherlands where grassland has been replaced by row crops has shown susceptibility of erosion to increase by 15 to 20 times (Van der Helm, 1987). Sediment in flood water can cause much damage to properties and drainage systems, as well as reducing in-channel capacity.

9.14.3 Research into the role of rural land management techniques has been made a priority by Defra (2005). If a typical farm, or small catchment, were to sacrifice 2-10% of its landscape to water attenuation and flood mitigation, it would dramatically change the characteristics of the runoff regime (Quinn et al 2007). Runoff Attenuation Features (RAFs) can be implemented within a farm to contribute to this type of flood mitigation.

9.14.4 RAFs are soft engineered interventions that are more desirable than traditional engineering solutions, due to their low cost and the cumulative benefits to all downstream flood sites. Belford burn, Northumberland, has implemented a variety of RAFs to alleviate the downstream flooding in Belford - a village which has flooded seven times in seven years.

9.14.5 RAFs are most effective when river-floodplain connectivity is existent and where topography allows natural storage. Permeable timber barriers are designed to hold water without creating an attenuation pond with the shallow soils of upland catchment. The barrier implemented in the Belford Burn catchment can divert up to 30 percent of the flow from the stream into attenuation structures. Overland flow disconnection ponds are storage areas which intercept overland flow. They are ideal for disrupting fast surface runoff pathways during peak flow events.

9.14.6 Large woody debris is employed within the riparian zone to increase channel roughness which leads to reduced flow velocity, increased sedimentation and spillage onto the connected floodplain. These structures also create complex microhabitat for both aquatic and terrestrial organisms, as well as contribute to nutrient cycling.

9.14.7 Other RAF structures such as swales and infiltration trenches are depressions to alter the conveyance of water through the catchment by encouraging infiltration. Subsurface flow is much slower, therefore diminishing the peak flow and extending lag time in the flood hydrograph, as well as being efficient at removing agricultural chemical pollutants for the water. Infiltration trenches cost more than swales due to the stones that are used in construction to line the trench.

9.14.8 Farming Floodplains for the Future (Defra, 2010) exhibits case studies of farming techniques for sustainable flood management. This scheme was employed across the Sow and Penk catchments (251km² and 350km², respectively) in Staffordshire at 50 sites to create 22,100 m³ of flood storage. Although this approach only contributed to 2.61% of the target volume for flood storage, cost-benefit analysis has shown that it has been a worthwhile investment. Table 39 summarises the separate parts to the scheme.

9.14.9 Other case studies to note are can be found in Working with Natural Processes to Manage Flood and Coastal Erosion Risk (2010, Environment Agency). Particular examples include the Fordingbridge Flood Alleviation Scheme in Hampshire which saw the reinstatement of 30ha floodplain grazing marsh as well as washland and wetland creation. This scheme encouraged 7m³/s to divert onto the floodplain and into upland flood storage and came to a total cost of £5.3m. This may be an appropriate approach to using pastoral farming land for upland attenuation.
9.14.10 In the River Hull catchment, farming is largely arable which is suitable to accommodate RAFs. Figure 31 below shows the sub-catchments where NFM may be applicable. Sites for NFM would be identified by their distance from main watercourses, floodplain connectivity, terrain type, land ownership and feasibility. In areas of pastoral farming, reconnecting the river to the floodplain and allowing this to flood in peak flow will be a sustainable approach and provide further storage in upland areas. The River Hull catchment also has similar characteristics to those of the Sow and Penk, despite being much greater in area, thus implying that the methods in this case study could be implemented across the River Hull basin on greater scale.

9.14.11 Floodwater attenuation could also occur in urban areas of the basin to reduce the rate of surface water flows. Sustainable drainage systems (SuDS) are features similar to RAFs that can be implemented in urban zones and can involve green roofs, surface water attenuation ponds, permeable surfacing and rain gardens. £15m worth of urban SuDs have been implemented within a district in Malmo, Sweden to provide protection from a 1/50yr rainfall event through 9500m² of green roofs and 70% of run off being stored in surface water attenuation ponds. There may be areas within the urban districts of the

Table 39 - Case studies within the Farming Floodplains for the Future Scheme (Defra, 2010)

<table>
<thead>
<tr>
<th>Site</th>
<th>Catchment</th>
<th>Techniques</th>
<th>Scheme size</th>
<th>Volume stored</th>
<th>BAP Habitat</th>
<th>Cost (Total)</th>
<th>Cost /m³ stored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Church House Farm</td>
<td>Sow</td>
<td>1,2</td>
<td>5.0</td>
<td>4050</td>
<td>3.0ha floodplain grazing marsh (FGM) created and 2.0ha restored, 3 ponds created, 335m river channel enhanced.</td>
<td>£10,893</td>
<td>£2.69</td>
</tr>
<tr>
<td>Little Horsely Farm</td>
<td>Sow</td>
<td>2,3</td>
<td>1.0</td>
<td>275</td>
<td>0.8ha lowland meadow (LM) restored, 2 ponds created</td>
<td>£7993</td>
<td>£22.371</td>
</tr>
<tr>
<td>Old Hattons Farm</td>
<td>Penk</td>
<td>4</td>
<td>0.07</td>
<td>240</td>
<td>2 ponds restored</td>
<td>£4261</td>
<td>£1.09</td>
</tr>
<tr>
<td>Fieldhouse Farm (The dingle)</td>
<td>Sow</td>
<td>4,5,6,7</td>
<td>4.33</td>
<td>1450</td>
<td>4.25ha FGM restored, 2 ponds created</td>
<td>£4379</td>
<td>£3.02</td>
</tr>
<tr>
<td>Izaak Walton Golf Course</td>
<td>Sow</td>
<td>1,4,6</td>
<td>0.6</td>
<td>2050</td>
<td>0.21ha FGM restored, 2 ponds created</td>
<td>£2453</td>
<td>£1.2</td>
</tr>
<tr>
<td>Bellfields Farm</td>
<td>Penk</td>
<td>2,3</td>
<td>4.2</td>
<td>6150</td>
<td>2 ponds created</td>
<td>£5652</td>
<td>£0.92</td>
</tr>
<tr>
<td>Deepmore Farm</td>
<td>Penk</td>
<td>2,3</td>
<td>4.5</td>
<td>6750</td>
<td>4.5ha LM restored, 2 ponds created</td>
<td>£18,069</td>
<td>£2.12</td>
</tr>
<tr>
<td>Fieldhouse Farm (Woodland)</td>
<td>Sow</td>
<td>8</td>
<td>0.87</td>
<td>1125</td>
<td>0.87ha broadleaved woodland restored</td>
<td>£5670</td>
<td>£5.04</td>
</tr>
</tbody>
</table>

River Hull catchment which could alleviate surface water flows through the use of urban SuDS.

9.14.12 The aim in this option is to attenuate the 1% AEP peak flow upstream across a greater area of upland catchment through soft engineering, rather than in large, hard engineered offline storage areas further downstream (Option 3b, 4e, 4f). For example, peak flow of Old Howe is 7.2m$^3$/s, which is calculated to be reduced to 4m$^3$/s with effective NFM employed. Further research will be required to ascertain how much farmland should be designated to RAFs to achieve that level of attenuation for Old Howe and other similarly small catchments.

Figure 31 - Upland hydraulic catchments

9.14.13 In the River Hull catchment, farming is largely arable which is suitable to accommodate RAFs. Sites for NRM would be identified by their distance from main watercourses, floodplain connectivity, terrain type, land ownership and feasibility. However, with this strategy option, it will be more important for land owners to adopt this approach and be involved in catchment-scale flood management and have more responsibility over such schemes.

9.14.14 In general, the creation of new woodland has the potential to support upland attenuation. It has the ability to hold water and reduce the quantity entering river
systems at times of peak flows, and can help combat soil erosion and wash-off, and can support woody energy crop production (a feature of the York & North Yorkshire LEP’s economic strategy). The local Heywoods initiative can be a key partner.

**Benefits**

9.14.15 This option is not predicted to prevent 1% AEP return period flood inundation at any particular location in the modelled extent; instead, it reduces the extent and peak depth of flooding at any given location. An 8% average reduction in inflow peaks is predicted to reduce the peak 1% AEP fluvial inundation volume by approximately 3%. The same percentage flow reduction has a marginally larger mitigation impact at lower return periods, with the peak 20% AEP fluvial inundation volume predicted to be reduced by approximately 5%. A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.

**Costs**

9.14.16 The overall cost of Natural Flood Management (NFM) is dependent on the amount of area designated to RAfs. The Environment Agency has produced an overview of costs for various rural drainage systems that could be implemented across the catchment. A case study scheme involving a sediment trap and redirection of ditches cost £1400 for materials and relied on farmers to carry out groundwork and maintenance. Smaller scale projects across the catchment will be considerably lower in cost than implementing a large hard engineered solution.

9.14.17 Using the case studies from Farming Floodplains for the Future (EA, 2010) it has been found that the average cost per hectare for the schemes is £3193. If 10-25% of agricultural land within the River Hull upper catchments is put aside for NFM, then this could cost between £93,300 and £233,100. Using the higher figure and adding 60% optimism bias we come to a final figure of £372,960. However not all of the land put aside would need to be adapted to be appropriate for NFM, therefore these figures are likely to be an over-estimation.

<table>
<thead>
<tr>
<th>Runoff Attenuation Feature</th>
<th>Description</th>
<th>Construction cost</th>
<th>Operational cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Wetland</td>
<td>£5000, increased if liner required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pervious surfaces</td>
<td>Recycled plastic paving</td>
<td>£200 for 10m²</td>
<td></td>
</tr>
<tr>
<td>Biobeds</td>
<td>£3500-7000 dependent on characteristics. Increased if pump required</td>
<td>Mixture to be replaced every 5-8 years.</td>
<td></td>
</tr>
<tr>
<td>Swales</td>
<td>£10-15/m³</td>
<td>£0.1/m²</td>
<td></td>
</tr>
<tr>
<td>Infiltration trenches</td>
<td>£55-65/m³</td>
<td>£0.2-1/m³</td>
<td></td>
</tr>
<tr>
<td>Barriers</td>
<td>£28000 for 5m of 1.0m high concrete wall, Ochre pellet trap and Ochre pellets.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands within ditches</td>
<td>For 30m ditch</td>
<td>£5000 – Sedge £6000 - Willow</td>
<td></td>
</tr>
<tr>
<td>Detention basin</td>
<td>£15 - 20/m²</td>
<td>£0.1 – 0.3/m²</td>
<td></td>
</tr>
<tr>
<td>Retention pond</td>
<td>£5000, increased if liner required.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9.14.18 Using average cost per m³ of storage from these case studies, if NFM was to provide flood storage equivalent to that of the proposed offline storage at Weel (Option 4f), then it would cost approximately £3.65m. Although it is very unlikely for this amount of storage to be created through NFM, it is a considerably more affordable and viable option.

**Economic summary**

**Table 41 - Damages for Option 8a**

<table>
<thead>
<tr>
<th></th>
<th>Direct and indirect damages to Property</th>
<th>Direct and indirect damages to Agriculture</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Damage (£m)</td>
<td>162.4</td>
<td></td>
<td>Total PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>7.0</td>
<td></td>
<td>Total PV Benefit (£m)</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
<td>154.7</td>
<td></td>
<td>PV Cost (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>0.2</td>
<td></td>
<td>Benefit Cost Ratio (BCR)</td>
</tr>
<tr>
<td><strong>Total PV Damage (£m)</strong></td>
<td>317.1</td>
<td></td>
<td><strong>7.2</strong></td>
</tr>
<tr>
<td><strong>Total PV Benefit (£m)</strong></td>
<td>7.2</td>
<td></td>
<td><strong>3.2</strong></td>
</tr>
<tr>
<td><strong>PV Cost (£m)</strong></td>
<td>3.2</td>
<td></td>
<td><strong>2.25</strong></td>
</tr>
</tbody>
</table>

9.14.19 The following table summarises the economic appraisal of this option.

**Funding and contributions**

9.14.20 Application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. The table also identifies the scale of external contributions required. The above assessment shows the worst case calculator as realistically future maintenance would not be a cost to the EA and would instead come from other sources, this would bring the PV cost down significantly making more of a case for the capital investment.

9.14.21 It is envisaged the majority of the funding would be obtained from alternative sources, primarily via NELMS - the replacement for Countryside Stewardship, which is intended to promote sustainable land management on farms and which benefits water quality, flood management and ecology. Land owners are able to apply for grants from July 2015 and agreed land management is to commence by January 2016. Other potential funding sources include the local Heywoods woodland planting initiative, and via both Local Economic Partnerships’ funding.

**Consultation comments**

9.14.22 Although there was general support and interest in this option, many respondents queried whether the benefits would be as large as predicted and in what locations it might occur. More details were requested about how it is to be funded and delivered. The locations where this approach are likely to be feasible are shown above. Flood volume reductions are based on the known effects from schemes elsewhere.
As the Preferred Approach summary indicated, it is envisaged that funding would primarily come from the replacement for Countryside Stewardship farm payments, which is due to commence in 2015/16. Funding may also be possible from the two Local Enterprise Partnerships and other local initiatives (such as Heywoods). Section 11 below deals with delivery.

**SEA appraisal, mitigation and enhancement**

The SEA could not assess any direct impacts on designated assets, as details of any proposed works have not yet been defined. A significant number of designated and non-designated cultural assets could potentially be affected by individual elements of this option, both directly (i.e. physically) and indirectly (i.e. through a change in setting etc.).

Initial scheme proposals could be drawn up based on the locations of existing designated assets, and then an appropriate level of survey, initially involving a detailed desk-based assessment and walkover inspection but possibly also including some localised intrusive investigations to characterise the resource, will need to be undertaken to ensure that all potential assets within the development footprints have been identified at early stage. Consultations will need to be held with the Humber Archaeology Partnership and local authority conservation officers as part of this process. Results from these surveys will be fed into the design process, so that cultural heritage issues are addressed from an early stage of development. Although the avoidance of designated and non-designated assets would be a priority, it may be necessary to undertake further investigations and surveys to adequately record and/or remove identified assets, should other factors determine scheme locations.

The water environment, the SEA considers potential adverse effects may arise during the implementation stage across a range of construction activities including excavation of ponds and trenches. Mitigation through careful site management is considered to be a key measure in respect of water environment. Stockpiles of materials will be segregated and stored away from flow paths into the River Hull system.

Reinforced turf mats can be used along new drains, pond edges and swales to ensure that topsoil does not erode before it has vegetated. Similar to Option B it is recommended that a CEMP be prepared in advance of any works.

The SEA identifies that the nature of the option is likely to lead to beneficial diversification of landscape features and biodiversity, particularly through the creation of ponds, hedgerows and woodland. Until details are worked up, it is not possible to say what cultural heritage enhancements may arise.

**Sluicing for tidal exclusion (11)**

**Introduction**

This series of options looks at using the River Hull Tidal Surge Barrier (TSB) or another mechanism or structure to exclude the tidal ingress and therefore allowing space to store water behind the barrier. Various methods were investigated and they are described below.

**Alternative use of the River Hull TSB (11)**

**Description**

The River Hull TSB is designed to remain open unless water levels at the outfall into the Humber are forecast to exceed 4.25m AOD. Since a significant length of the River Hull
is tidally-impacted, this offers substantial protection against tidally-induced flood risk. However, tidal peaks below 4.25m AOD are also capable of substantially increasing flood risk associated with a given fluvial event, such that TSB operation at lower tides offer the potential to reduce flood risk although noting that optimisation is needed to ensure that unnecessary closure of the TSB (hence cessation of River Hull discharge into the River Humber) does not increase flood risk. This proposed method is called Sluicing for Tidal Exclusion (SfTE). Figure 32 shows the TSB from one of the surveys which were taken for the strategy.

9.15.3 Sensitivity analyses were performed in order to optimise the barrier closure threshold and to ensure that unnecessary closure of the tidal barrier (hence cessation of River Hull discharge into the River Humber) does not have adverse impact and actually increase flood risk. Modelling a range of barrier closure thresholds demonstrates that a 2m AOD threshold offers the optimal benefit of reduced tidal propagation without detrimentally restricting river outflow.

9.15.4 This option therefore entails operation of the TSB under the same basic operational regime as at present, but with a reduced forecast barrier activation level of 2m AOD instead of 4.25m AOD in response to extreme storm events. The conditions under which SfTE is required are only likely to occur rarely within a typical year. For the purpose of cost estimation, it should be conservatively assumed that closure is needed on average for 2 x 5 day periods per year at high tide. The EA has discretion to alter the barrier’s operational arrangements, and has been trialling more frequent use (to deal with non-surge tides). Further consideration needs to be given to the suggested changes.

Benefits

9.15.5 By modulating superposition of the fluvial peak with tidal peaks in the River Hull, this option reduces peak inundation volume in the tributaries of the River Hull, primarily in
the Mickley Dike and Beverley and Barmston Drain. For the 1% AEP return period event, modelling predicts this option to reduce peak inundation volume in the River Hull system by approximately 13%.

9.15.6 This option is not predicted to prevent 1% AEP return period flood inundation at any particular location in the River Hull system; instead, it reduces the extent and peak depth of flooding at any given location. It will also slightly increase the critical return period associated with the triggering of fluvial flooding at any given location. However, as an example, estimated changes to water levels at Wilholme PS outfall are estimated to be 125mm lower at peak water levels, and 258mm lower at non-peak levels for this return period.

9.15.7 The full benefit of this option requires implementation of the proposed lower activation level at the start of the extreme storm event, to ensure maximum benefit.

9.15.8 However, further analysis demonstrates that sensitivity to delayed implementation is relatively low. For the design 75hr critical storm event, implementation at the start of the event achieves a 13.5% reduction in peak 1% AEP inundation volume. If implementation is delayed until 12 hrs after the start of the event, a reduction of 12.6% is achieved. Similarly, a 24hr delay achieves an 11% reduction, and even a 36 hr delay achieves a 9% reduction. Depending upon the cost of each operation of the tidal barrier, it may therefore be beneficial to delay implementation of the lowered activation threshold until the extremity of the storm event is confirmed, to minimise the cost associated with “false events” (i.e. intense rain bursts of insufficient duration to cause flood risk).

9.15.9 Discussions have been held with the EA’s operational engineers to ensure that no detriment will be caused to the barrier through its additional use. Further investigations and assessments will be required however it has been agreed that a new set of operational rules will be drawn up in draft that seek to:

- set barrier activation level of 2m AOD instead of 4.25m AOD in response to extreme storm events
- limit closure hours per event, as far as practicable, to minimize adverse effects to navigation
- bring forward significant engineering reviews to five yearly intervals to ensure the structural and operational integrity of the barrier is maintained.

Economic summary

9.15.10 The table below summarises the economic appraisal of this option.

Table 42 - Damages for Option 11

<table>
<thead>
<tr>
<th></th>
<th>Option 11: Increased use of Hull Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct and indirect damages to Property</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
<td>159.9</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>Direct and indirect damages to Agriculture</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
<td>154.2</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Total PV Damage (£m)</td>
<td>314.1</td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
<td>10.3</td>
</tr>
<tr>
<td>PV Cost (£m)</td>
<td>5.8</td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
<td>1.77</td>
</tr>
</tbody>
</table>
Funding and contributions

9.15.11 The table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. It also identifies the scale of external contributions required. This solution has been given indicative costs.

Table 43 - Benefits option 11

<table>
<thead>
<tr>
<th>Option 11: Increased use of Hull Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost (£m) 2064</td>
</tr>
<tr>
<td>PV Benefit (£m) 2064</td>
</tr>
<tr>
<td>Raw PF Score</td>
</tr>
<tr>
<td>FDGiA Contribution</td>
</tr>
<tr>
<td>Required Contributions</td>
</tr>
</tbody>
</table>

Consultation comments

9.15.12 Several consultees welcomed the potential of this solution. They were extremely positive towards using an existing asset in an innovative way to prevent flooding from more than one source. One comment advised that the primary use should not be affected which is also the view of this strategy and therefore further investigation will be required moving forward.

SEA appraisal

9.15.13 No separate assessment has been made of this option. Assessment has been carried out against Option 11c below.

Alternative use of River Hull TSB and bypass culvert (11a)

Description

9.15.14 This option aims to alleviate flooding by safe closure of the Hull TSB during lower tides with the same basic principal as the option detailed above.

9.15.15 However, whilst operation of the River Hull TSB can be shown to prevent tidal surcharge, the barrier has a limited operational life. Repeated operation to coincide with tidal conditions over the duration of a flood event could be shown to decrease the life of the structure and cause a detriment to its primary use (this will be investigated further).

9.15.16 The preclusion of tidal influences over the duration of a flood event can be achieved by closing the barrier over a period of several days. However, during this time the river flows would need to be discharged using the head difference at low tide. A solution to this problem could be achieved by the construction of a bypass culvert which would pass water through at low tide but prevent inflow at high tide using a flap valve. Figure 33 below illustrates an indicative route of the culvert and would consist of headwall structures at both ends. Closure and opening controls by form of a penstock would be required at the upstream and flap valve downstream of the structure.

9.15.17 The option would consist of a two metre diameter pipe externally corrugated and lightweight such as high density polyethylene. The construction of two headwall structures at the upstream and downstream ends of the culvert. Penstock control
would be required at the upstream and a flap valve structure downstream. Costs associated with dewatering the Construction site using coffer dams and pumps are included. Other risks associated with deep excavations are involved such as service diversions, voids due to the old dock etc.

9.15.18 The invert level of the culvert has been determined by the median of the tidal level records currently calculated at approximately 0.0m AOD. The capacity of the culvert will be approximately 7.5m$^3$/s based on an excess of upstream head above 2.0m AOD.

![Figure 33 - Indicative route of culvert at Hull TSB](image)

**Benefits**

9.15.19 Benefits would be expected to be similar to those indicated in Option 11. However, as the culvert would have a reduced flow, restricted to 7.5m$^3$/s, there would be a longer period of time to empty stored storm water in the River Hull side of the barrier. This would reduce overall flood risk benefit.

**Costs**

9.15.20 The cost estimates have been drawn up based on quantities which have been calculated from the assumed route of the culvert. The following is a summary of the assumptions and cost estimates:

- No inclusion made for purchase of land
- No major diversion of existing sewer pipes

**Table 44 - Option 11a capital cost**

<table>
<thead>
<tr>
<th>OPTION 11a - CAPEX</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff costs for admin and legal fees</td>
<td>450,000</td>
</tr>
<tr>
<td>Consultancy fees</td>
<td>150,000</td>
</tr>
<tr>
<td>Site investigations</td>
<td>100,000</td>
</tr>
<tr>
<td>Construction</td>
<td>661,000</td>
</tr>
<tr>
<td>Environmental Mitigation</td>
<td>10,000</td>
</tr>
<tr>
<td>Site Supervision</td>
<td>150,000</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>1,521,000</td>
</tr>
<tr>
<td>60% optimum bias</td>
<td>912,600</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2,433,600</td>
</tr>
</tbody>
</table>
Economic summary

9.15.21 The following table summarises the economic appraisal of this option:

| Table 45 - Damages for option 11a |
| Option 11a: Increased use of Hull Barrier plus bypass culvert |
| Direct and indirect damages to Property |
| PV Damage (£m) | 159.9 |
| PV Benefit (£m) | 9.6 |
| Direct and indirect damages to Agriculture |
| PV Damage (£m) | 154.2 |
| PV Benefit (£m) | 0.7 |
| Total |
| Total PV Damage (£m) | 314.1 |
| Total PV Benefit (£m) | 10.3 |
| PV Cost (£m) | 8.0 |
| Benefit Cost Ratio (BCR) | 1.29 |

| Table 46 - Benefits of option 11 |
| Option 11a: Increased use of Hull Tidal Surge Barrier |
| PV Cost (£m) 2064 | 6.9 |
| PV Benefit (£m) 2064 | 3.6 |
| Raw PF Score | 4% |
| FDGiA Contribution | 0.2 |
| Required Contributions | 6.7 |

Funding and contributions

9.15.22 The table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this Option. The table also identifies the scale of external contributions required.

Construction of tidal sluice near Ennerdale Bridge (11b)

Description

9.15.23 This option aims to minimise the impact of tidal propagation into the River Hull upon exacerbating flood risk associated with an extreme fluvial event, noting that peak water levels in the majority of the River Hull are produced by the superposition of fluvial flow peaks combined with high tides.
This option entails construction of a new sluice or lock structure, specifically designed to limit tidal propagation during and immediately after extreme storm events. This is an alternative to using the existing River Hull TSB to produce similar benefit, considered in Option 11. Figure 34 indicates the location of a proposed sluice immediately downstream of the Ennerdale (A1033) Bridge, as well as the existing River Hull Tidal Barrier. The proposed sluice is located adjacent to the Bransholme lagoon, upstream of the Bransholme SWPS outfall.

Figure 34 - Proposed location of Tidal sluice for Option 11b

At the location of the proposed sluice, the width of the River Hull channel is approximately 16 m, with a bed level of -1.8m AOD. These dimensions were used as the basis for the proposed sluice. It is assumed that the sluice would be activated based on telemetry linked to water levels in the river immediately downstream. Trial simulations using differing activation thresholds between 2.7m AOD and 3.4m AOD indicate that a 3.2m AOD activation threshold produces the maximum reduction in peak 1% AEP water levels upstream of the sluice.

It is therefore recommended that the sluice remains open unless both the following conditions are satisfied:

a) An extreme storm incident on the River Hull catchment
b) Water levels immediately downstream of the sluice exceed 3.2m AOD.

The conditions under which the sluice is required to close are only likely to occur rarely within a typical year. For the purpose of cost estimation, it should be conservatively assumed that closure is needed on average for 2 x 5 day periods per year.
Benefits

9.15.28 For the 1% AEP return period event, modelling predicts this option to reduce peak inundation volume in the River Hull system by approximately 4%. By comparison, changing the activation threshold of the River Hull TSB (Option 11) achieves a more substantial reduction of 13%.

9.15.29 This option is not predicted to prevent 1% AEP return period flood inundation at any particular location in the River Hull system; instead, it reduces the extent and peak depth of flooding at any given location. It will also slightly increase the critical return period associated with the triggering of fluvial flooding at any given location. Modelling using InfoWorks© ICM does not readily permit representation of a lock structure; however, it is likely that the use of a lock instead of a sluice will produce comparable mitigation benefit.

9.15.30 Considering the additional capital and operational/maintenance costs of this proposed new structure, as well as its reduced effectiveness relative to Option 11, this option is unlikely to be economically feasible and therefore costs and economic appraisal were not considered any further.

9.15.31 A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.

New structure at River Hull mouth (11c)

Description

9.15.32 Modulation of the superposition of the fluvial peak with tidal peaks in the River Hull by means of the Hull Tidal Barrier (Option 11) even with a bypass culvert (Option 11a) would be restricted by the operational life limits of the barrier. At present, the barrier has a further design life of around 30-40 years, due to recent investment from the EA, with an operational frequency of approximately six closures every year. The use of the barrier to prevent tidal inundation at times of fluvial flooding would increase the number of closures to eight per year.

9.15.33 This option explores the addition of a tidal mitre-gate at the mouth of the River Hull for SfTE which will supplement and eventually replace the use of the Hull Tidal Barrier. Further advantages to be gained by this scheme include provision for a higher level of tidal protection which may become necessary as sea levels increase.
Figure 35 above shows the proposed location of new gates, where use can be made of the existing walls constructed as part of the surge barrier. It also shows a pair of simple mitre gates, although other options, such as sector gates could also be considered.

Benefits

9.15.35 All benefits and damages figures would be expected to be the same as changing the activation levels of the TSB as is explained for option 11. This is because this structure would sit at the same position of the barrier and operate with the same hydraulic restrictions.

Economic summary

Table 47 - Damages option 11c, new tidal sluice

<table>
<thead>
<tr>
<th>Option 11c New Tidal Gates</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct and indirect damages to Property</td>
</tr>
<tr>
<td></td>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td></td>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td></td>
<td>Direct and indirect damages to Agriculture</td>
</tr>
<tr>
<td></td>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td></td>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td></td>
<td>Total PV Damage (£m)</td>
</tr>
<tr>
<td></td>
<td>Total PV Benefit (£m)</td>
</tr>
<tr>
<td></td>
<td>PV Cost (£m)</td>
</tr>
<tr>
<td></td>
<td>Benefit Cost Ratio (BCR)</td>
</tr>
</tbody>
</table>

9.15.36 The following table summarises the economic appraisal of this option.
Funding and contributions

9.15.37 The table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this Option. The table also identifies the scale of external contributions required.

Table 48 – Benefits options 11c

<table>
<thead>
<tr>
<th>PV Cost (£m) 2064</th>
<th>15.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Benefit (£m) 2064</td>
<td>3.6</td>
</tr>
<tr>
<td>Raw PF Score</td>
<td>2%</td>
</tr>
<tr>
<td>FDGiA Contribution</td>
<td>0.2</td>
</tr>
<tr>
<td>Required Contributions</td>
<td>15.1</td>
</tr>
</tbody>
</table>

Consultation comments

9.15.38 Several consultees expressed a hope that the proposed mitre gates could be could be closed on a semi-permanent basis to provide a high enough water level within the river, especially in the old harbour area in the city, to keep river sediments permanently covered. Conversely, there were concerns over potential negative effects on navigation and on aspirations to increase river traffic movements.

9.15.39 The City Council and its partners have twice looked at the possibility of achieving this. The last study, in 2006, identified potential costs of £200m. Most of these were associated with dealing with the upstream consequences of high permanent water levels, rather than the cost of the barrier’s construction, as effects would be felt up to the tidal limit at Hempholme weir. Although such use would have bought measurable economic benefits and helped promote city centre development opportunities, the level of public sector funding required could not be identified. Most of those potential sources no longer exist. As semi-permanent closure would not be required for flood risk management purposes, national flood defence funding would not be available to contribute to the indirect costs of re-engineering the whole of the river system.

SEA appraisal, mitigation and enhancement

9.15.40 The SEA concludes that as this option involves construction of a new tidal barrier for which will be activated more frequently (at tides of 2m AOD rather than 4.25m AOD as at present), there is a possibility that increased closure will restrict fish movements between the River Hull and Humber Estuary for species including eels and sea lamprey. The risk of compromising fish movements is considered to be small (unlikely) as the river will continue to discharge into the Humber Estuary in the usual way on ebbing and low tides and all high tides less than 2m AOD. Mitigation will include the monitoring of fish movements to ascertain the impact of increased tidal barrier use.

9.15.41 There are unlikely to be any direct physical impacts on identified designated cultural heritage assets, but it is possible that some non-designated buried assets (both currently known and unknown) will be affected, both within this short section of river channel and along the adjacent banks. An appropriate level of research and investigation will need to be carried out to ensure that any such sites are identified at an early stage of
scheme design. Any potential visual impacts on designated or non-designated assets should also be considered and addressed as part of the design process.

9.15.42 Management of construction activities is considered to be a key mitigation factor to reduce the risk of pollution to the water environment. It is recommended that during any detailed design and construction planning that a Construction Environmental Management Plan (CEMP) be prepared.

9.15.43 The design of the proposed option means that there are unlikely to be any direct cultural heritage enhancements resulting from the implementation of this scheme, although information relating to the history and importance of the area could be included in any general enhancement work (e.g. information panels, notice boards etc.) in this area which already attracts a certain level of tourist footfall.

Tidal sluice at the River Hull mouth (11d)

9.15.44 A further development of the tidal mitre gate option is to introduce a full tidal lock with bypass sluice. This option would maintain a relatively constant water level upstream of the lock and remove the tidal influence to the river completely, whilst still allowing navigation. This would change the characteristics of the river, especially within the Hull City boundary and would result in possible environmental development and regeneration opportunities beyond the scope of this report.

9.15.45 The benefits to peak inundation will be reduced in comparison to the tidal gate option due to the reduction of potential storage volume for flood water. This could be mitigated by sluicing off water at low tide in preparation for a flood event but this would need to be planned and incorporated into the rules of navigation for the river.

9.15.46 The effect of the change in river characteristics due to a tidal lock would extend to the whole of the tidal system between the river mouth and Beverley. Further study will be required to establish the effects upon all outfalls into the River Hull. An example would be the Beverley and Barmston Drain, which currently discharges into the River Hull under gravity at low tide. A further effect of the removal of tidal influence would be a reduction in sediment transport and deposition from the tidal inflow.

9.16 Bransholme flood mitigation (13)

Description

9.16.1 The Bransholme surface water pumping station is regarded as a potential constraint upon surface water drainage from the Bransholme area discharging into the River Hull. This option examines the potential for increased pump capacity at this location to mitigate flood risk associated with surface water network backup.

9.16.2 Water is pumped east to west towards the discharge sluices, with temporary storage provided by the Bransholme lagoon in the event of high water levels in the River Hull at the time of pumping. In the event of severe backup, the lagoon is capable of directly overtopping via high-elevation weirs into the River Hull.

9.16.3 The Bransholme PS consists of four pumps of approximately 0.6m³/s capacity. This option proposes increasing the available pumping capacity at the PS to 23m³/s via the replacement of existing pumps.

9.16.4 In contrast to the majority of proposed options in this study, this option is not targeted at resolving predicted fluvial flooding. Instead, this option aims to mitigate network flood risk, although the potential for high River Hull water levels to modulate discharge
behaviour means that fluvial behaviour cannot be neglected. As such, modelling in relation to this option was conducted using an integrated model.

9.16.5 While the 75 hour event has been identified as critical in relation to fluvial flood risk, flooding from the Bransholme network was found by analysis to be greatest for a 10 hour event. As such, analysis for this option considers a 10 hour critical event duration in the derivation of rainfall and fluvial flow inputs to modelling.

Benefits and analysis

9.16.6 For a 75 hour storm event (i.e. the critical event in relation to fluvial flood risk for the study extent), flows into the Bransholme PS inlets are low enough such that the additional pump capacity is not utilised. This indicates that, for longer storm events of lower peak rainfall intensity, the pumping station is not a constraint. For a 10 hour critical storm duration, modelling predicts that this option is capable of reducing the peak 1% AEP inundation volume in the area served by the Bransholme surface drainage network by approximately 38%, from an estimate for current conditions of 125,260m$^3$ to 77,133m$^3$ with provision of increased pump capacity. However, it is critical to note that, in addition to surface water drainage flooding addressed by this option, predicted flooding within the Bransholme area comes from multiple other sources:

- Flooding due to surcharging of the combined sewer network
- Rainfall-excess (i.e. pluvial) flooding upon localised topographic depressions with poor or no connectivity to a manhole of either the surface water or combined sewer network

9.16.7 Neither of these forms of flooding are capable of being directly addressed by this option. In the case of the latter, this flooding is not constrained by the capacity of the existing surface water drainage network, but by limitations in the area topographically draining to any manhole within the network (this effect is partially realistic, due to real gaps in the effective catchment area of the surface water sewer network, and partially an artefact of limited representation of small-scale elements of the sewer network, such as individual points of entry via road gullies, etc.). For the 1% AEP, 75 hour event, analysis indicates that 60,594m$^3$ of pluvial flooding cannot be drained by the existing surface water and combined sewer networks for this reason. If this “undrainable” volume is excluded, this option is shown to achieve a 74% reduction in the remaining “drainable” peak flood volume. The residual 16,536m$^3$ flood volume is associated with two mechanisms:

a) Pluvial rainfall excess upon localised depressions with slow connectivity to a sewer manhole; if the rate of rainfall excess generation exceeds the rate of drainage into a sewer manhole, transient flooding will occur even if the manhole itself doesn’t flood. This element of flooding cannot be resolved by sewer up sizing, although it may be reduced by the addition of new sewer branches extending into affected areas (assuming flooding in a given location isn’t an artefact of limited model representation of the network, as discussed above).

b) Genuine combined sewer network manhole flooding, which is predicted to occur at multiple locations within the Bransholme area.

9.16.8 The combination of flooding from pluvial, surface network and combined network sources makes it difficult to assess the efficacy of this option in addressing its intended problem via flood inundation analysis alone. Additional analysis was therefore conducted examining predicted gross flood volumes from the Bransholme surface water network manholes only for the 10 hour duration event. Table 49 presents the predicted gross flood volume for the Bransholme surface water drainage network, as well as the predicted impact of this option upon reducing these flood volumes.
This analysis demonstrates that the Bransholme surface drainage network is not predicted to flood in response to the critical five year return period event. For the 10 year return period event, Option 13 is predicted to essentially resolve flood risk, while producing a substantial reduction in gross flood volumes at higher return periods.

Modelling was initially conducted based on Arup’s preferred operational rules (R03), which also match existing discharge consent, i.e.:

- **Penstocks open if river level is below 3.048m AOD, or if river level is below 3.80m AOD AND [river level is falling at least 30 mm per 10 minutes]**
- **Penstocks closed otherwise**

Comparing model predictions utilising these operational rules, for existing versus proposed pump capacities, gives the following volumetric flooding predictions for the 1% AEP event of 10 hour duration (i.e. critical duration with respect to network flood risk) and 75hr duration (i.e. critical duration with respect to River Hull system fluvial flood risk):

9.16.9 For the 10 hour event, the proposed increase in pump rate substantially alleviates sewer flood risk in Bransholme, while also reducing fluvial flood risk within the River Hull and Holderness Drain systems. For the 75 hour event, predicted peak flood volumes in the Bransholme area are within tolerance of baseline predictions (noting that a majority of the approx. 69,000m³ peak flood volume relates to accumulated pluvial flooding in areas not directly drained by the sewer network, i.e. to the north of Kingswood, and is therefore incapable of being mitigated by increased pump capacity), and a very small detriment (1,486m³ or approx. 0.015%) upon predicted River Hull peak flood volume. In relation to this predicted detriment:

- **Fluvial flooding from the River Hull is not predicted in the vicinity of Bransholme; this detriment relates to very small increases in peak inundation depth/extent at one or more locations of existing fluvial flood risk over 10km further upstream around the Roam Drain. Depending upon the additional spill locations (which we are still to assess in ArcGIS) for this detriment, there may be no appreciable increase in flood damage**

Table 50 - Predicted 1% AEP peak inundation volumes for the Bransholme surface drainage network service area

<table>
<thead>
<tr>
<th>Event</th>
<th>Existing Condition (m³)</th>
<th>Option 13 (m³)</th>
<th>Reduction (m³)</th>
<th>Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>75hr</td>
<td>69,196</td>
<td>69,190</td>
<td>6</td>
<td>0%</td>
</tr>
<tr>
<td>10hr</td>
<td>125,191</td>
<td>92,268</td>
<td>32,923</td>
<td>26%</td>
</tr>
<tr>
<td>10hr (drainable)</td>
<td>64,597</td>
<td>30,660</td>
<td>33,937</td>
<td>53%</td>
</tr>
</tbody>
</table>

Table 49 - Predicted reduction in gross surface water network manhole flood volumes associated with option 13 (based on 10hr duration event)

<table>
<thead>
<tr>
<th>Event</th>
<th>Existing condition (m³)</th>
<th>Option 13 (m³)</th>
<th>Reduction (m³)</th>
<th>Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>5yr</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10yr</td>
<td>7,019</td>
<td>50</td>
<td>6,969</td>
<td>99%</td>
</tr>
<tr>
<td>50yr</td>
<td>132,598</td>
<td>18,951</td>
<td>113,648</td>
<td>86%</td>
</tr>
<tr>
<td>1% AEP</td>
<td>271,129</td>
<td>53,654</td>
<td>217,475</td>
<td>80%</td>
</tr>
</tbody>
</table>
b) Based on model analysis, the detriment is caused simply by the higher pump rates permitting higher peak and cumulative discharges into the river preceding the fluvial peak. In particular, any increase in discharge to the river during rising tides will be carried up the River Hull, and contribute to worsening flooding once the fluvial event peaks (increased pre-peak river discharge during falling tides will have a detrimental effect, but a relatively smaller effect). Even though this early over-pumping is eventually “evened-out” by relatively lower pumping later in the event, it results in relatively more water being in the River Hull preceding the fluvial peak which is the most critical period with respect to flood risk.

c) There is an overall predicted small betterment over the combined Holderness Drain and River Hull systems. (Note that peak volumes for the Hull, Holderness Drain and combined system occur at different times, such that the combined peak is not the summation of the individual peaks.)

9.16.13 Alternative operation scenarios were assessed to determine whether predicted detriment based on the existing operational rules could be avoided. Alteration to pump activation levels was found to produce varying results without achieving the required “no worse than existing” predicted flood inundation volume. Lowering the threshold River Hull water levels at which the penstocks open and close was found to be more effective, with the following operational rules predicted to produce a net reduction in River Hull and Bransholme surface water network peak flood inundation:

a) Penstocks open if river level is below 2.8m AOD, or if [river level is below 3.50m AOD] AND [river level is falling at least 30 mm per 10 minutes]
b) Penstocks closed otherwise

9.16.14 Peak 1% AEP inundation predictions for this alternative operational regime are presented in Table 51. The table also indicates the impact of increased pump capacities plus altered penstock operation upon altering the predicted peak water levels within the Bransholme Lagoon relative to existing conditions. This indicates that, while peak levels are substantially increased, levels remain well below the design spill level of 5.15m AOD.

9.16.15 Note that model predictions indicate that some flexibility is possible in the composition of the targeted combined pump capacity of 24 m$^3$/s. Results shown in Table 53 relate to the existing pumps being changed to matching 6 m$^3$/s capacity pumps with no alteration to existing switch on and switch off levels. Further modelling demonstrates that a primary pump of 1 m$^3$/s capacity, with secondary pump of 3 m$^3$/s capacity, supported by two 10 m$^3$/s capacity pumps achieves similar benefit, and may provide improved operational efficiency.
As the combined option provides substantial mitigation of the peak inundation volume, there would be greater flexibility in the operational rules for the Bransholme pumps/penstocks if the upgrade is to be performed in combination with other elements of the combined option. Simulations are a worst case scenario and if combined with other options, the penstocks could be left open for more of the time, and the requirement for temporary storage of pumped water in the Bransholme lagoon would be lowered.

Table 51 - Predicted peak 1% AEP inundation volumes for Option 13, based on existing discharge consent operational rules for the discharge penstocks

<table>
<thead>
<tr>
<th>Integrated Model Option (10 min output)</th>
<th>1% AEP Peak Flood Inundation Volumes (m³)</th>
<th>Reduction in Total (m³)</th>
<th>Lagoo n Peak Level (m AOD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Holderness Drain</td>
<td>Bransholme</td>
<td>River Hull</td>
</tr>
<tr>
<td>Maintained (&quot;Baseline&quot;), 75hr event</td>
<td>5,927,692</td>
<td>69,195</td>
<td>10,142,013</td>
</tr>
<tr>
<td>Option 13, 75hr event</td>
<td>5,925,636</td>
<td>69,196</td>
<td>10,138,442</td>
</tr>
<tr>
<td>Maintained (&quot;Baseline&quot;), 10hr event</td>
<td>3,180,449</td>
<td>125,260</td>
<td>6,122,457</td>
</tr>
<tr>
<td>Option 13, 10hr event</td>
<td>3,168,964</td>
<td>77,130</td>
<td>6,120,851</td>
</tr>
</tbody>
</table>

be lowered.
Consultation comments

9.16.17 Concern focussed on the potential for the pumping station, when working at full volume, would add to flooding upstream. New operating rules have been proposed which would ensure this would not be allowed to happen. Following discussions and explanations between partners, a revised operational agreement has now been signed between YW and the EA which gives effect to these suggested new operational limits.

SEA appraisal, mitigation and enhancement

9.16.18 As this is a committed scheme that is under construction, the SEA has not assessed it. Mitigation is, in effect, a new set of operating rules to ensure there is no detriment upstream of the pumping station when it is at or near full capacity.

9.17 Combined options (14, 1c, 15)

Weel storage and tidal exclusion (14)

Introduction

9.17.1 Option 14 consist of different combinations of two or three of the Option series 4 and 11, aiming to indirectly alleviate the flooding in the Hull tributaries or Beverley and Barmston drain by reducing the flood water levels in the River Hull.

Combined Weel storage and modified use of the Hull TSB (14a)

Description

9.17.2 This option entails the combination of two options: alteration to the River Hull Tidal Barrier (TSB) activation level (Option 11) in combination with offline storage in the vicinity of Weel (Option 4f). Refer to the description of each option for further details. In this option combination, the change in tidal barrier activation level (i.e. 2m AOD) is
as per Option 11. However, due to the impact of this upon lowering peak water levels experienced in the Weel area, the spillway level must be lowered relative to the 3.2m AOD level used for Option 4f in order to provide a sizeable reduction. See Table 54.

9.17.3 From trials involving a range of spill elevations, it is proposed that a 160m section of the eastern bank of the River Hull (between [506697, 438421] and [506639, 438267]) is lowered to 3.0m AOD to create a spillway entry from the river into the proposed storage area. Based on this spillway, modelling indicates that a storage capacity of 806,911 m$^3$ (lower than that of option 4f) is required to contain spillwater generated in the period up to and including the fluvial inundation peak in the River Hull system for the critical 1% AEP event.

<table>
<thead>
<tr>
<th>Table 52 - The results from the respective scenarios of Option 14a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported volumes (m$^3$)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Required Storage Downstream</td>
</tr>
<tr>
<td>Max flood volume in upstream tributaries</td>
</tr>
<tr>
<td>Difference from base case</td>
</tr>
<tr>
<td>% Difference from upstream flooding areas</td>
</tr>
<tr>
<td>Max flood volume Beverley areas</td>
</tr>
<tr>
<td>Difference from base case</td>
</tr>
<tr>
<td>% difference (Beverley drain areas)</td>
</tr>
<tr>
<td>Total difference in flood volumes</td>
</tr>
<tr>
<td>Total % difference in flood volumes</td>
</tr>
</tbody>
</table>

The location for the proposed storage structure is to the east of the River Hull along the river reach south of Weel (refer to Option 4f). While the required extent of Option 4f was 67.8 ha, for this option combination the required area extent is reduced to approximately 41ha, such that the storage area can be placed within a suitable sub-
area of the extents indicated in Figure 23. The required storage capacity will be contained between an existing minimum ground elevation in the area of -0.65m AOD and the 3.0m AOD elevation of the spillway entry.

9.17.5 An additional “drowned weir” capacity will be provided by embanking the proposed storage area further to 3.3m AOD. This buffer capacity does not provide reduction in peak inundation volume/extent, but provides temporary storage to protect against tidal or secondary fluvial water level peaks which may occur after the storage area is filled to spillway level and before it begins to be drained. The estimated embankment requirement is for a 2,830m of the basin perimeter to be raised from current ground levels by an average of 2.4m. For details on how the filled storage area would be drained via the Holderness Drain, landscaping and excavations of minor drains, see the description of Option 4f.

Benefits

9.17.6 The main benefit of this option is reduction in the overall flood inundation volume. Modelling results have identified that the proposed spillway and storage area will reduce peak 1% AEP inundation volumes for the River Hull system by 17%. By comparison, Option 11 effects a 13% reduction in peak 1% AEP inundation volumes for the River Hull system, such that the additional benefit provided by combining Option 11 with the proposed Weel storage is relatively minor. Volumetrically, the proposed 806,911 m³ storage area is predicted to reduce peak inundation by 306,643 m³, whereas Option 11 provides a predicted 1,179,695 m³ reduction. On this basis, the combined option is unlikely to be cost effective compared to Option 11 alone.

Costs

9.17.7 The cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings. See 68 for summary of assumptions used in

<table>
<thead>
<tr>
<th>OPTION 14a - CAPEX</th>
<th>Assumption 1 (£k)</th>
<th>Assumption 2 (£k)</th>
<th>Assumption 3 (£k)</th>
<th>Assumption 4 (£k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff costs</td>
<td>£ 950</td>
<td>£ 950</td>
<td>£ 950</td>
<td>£ 950</td>
</tr>
<tr>
<td>Consultancy fees</td>
<td>£ 400</td>
<td>£ 400</td>
<td>£ 400</td>
<td>£ 400</td>
</tr>
<tr>
<td>Site investigations</td>
<td>£ 300</td>
<td>£ 300</td>
<td>£ 300</td>
<td>£ 300</td>
</tr>
<tr>
<td>Construction costs - Option 4f</td>
<td>£ 18,849</td>
<td>£ 18,020</td>
<td>£ 21,499</td>
<td>£ 32,719</td>
</tr>
<tr>
<td>Construction costs – Option 11</td>
<td>£ 661</td>
<td>£ 661</td>
<td>£ 661</td>
<td>£ 661</td>
</tr>
<tr>
<td>Environmental mitigation</td>
<td>£130</td>
<td>£ 130</td>
<td>£ 260</td>
<td>£ 260</td>
</tr>
<tr>
<td>Supervision</td>
<td>£ 350</td>
<td>£ 350</td>
<td>£ 350</td>
<td>£ 350</td>
</tr>
<tr>
<td>Land</td>
<td>£ 3,600</td>
<td>£ 3,600</td>
<td>£ 3,600</td>
<td>£ 3,600</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>£ 25,240</td>
<td>£ 24,450</td>
<td>£ 28,020</td>
<td>£ 39,240</td>
</tr>
<tr>
<td>60%</td>
<td>£ 15,144</td>
<td>£ 14,670</td>
<td>£ 16,812</td>
<td>£ 23,544</td>
</tr>
<tr>
<td>TOTAL</td>
<td>£ 40,384</td>
<td>£ 39,120</td>
<td>£ 44,832</td>
<td>£62,784</td>
</tr>
</tbody>
</table>
Option 14a. Land may need to be acquired by Compulsory Purchase Order (CPO).

**Economic summary**

**Table 54 - Damages option 14a**

<table>
<thead>
<tr>
<th>Option 14a: Offline Storage and Increased Use of Hull Barrier</th>
<th>Direct and indirect damages to Property</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PV Damage (£m)</td>
<td>153.3</td>
</tr>
<tr>
<td></td>
<td>PV Benefit (£m)</td>
<td>16.1</td>
</tr>
</tbody>
</table>

**Table 54 - Damages option 14a**

<table>
<thead>
<tr>
<th>Option 14a: Offline Storage and Increased Use of Hull Barrier</th>
<th>Direct and indirect damages to Agriculture</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PV Damage (£m)</td>
<td>154.2</td>
</tr>
<tr>
<td></td>
<td>PV Benefit (£m)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Total**

| | Total PV Damage (£m) | 307.5 |
| | Total PV Benefit (£m) | 16.8 |
| | PV Cost (£m) | 42.2 |
| | Benefit Cost Ratio (BCR) | 0.40 |

9.17.8 The following Table 54 summarises the economic appraisal of this option.

**Funding and contributions**

9.17.9 The table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. The Table 55 also identifies the scale of external contributions required.

**Table 55 - Benefits option 14a**

<table>
<thead>
<tr>
<th>Option 14a: Offline Storage and Increased Use of Hull Barrier</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost (£m) 2064</td>
<td>41.2</td>
</tr>
<tr>
<td>PV Benefit (£m) 2064</td>
<td>10.0</td>
</tr>
<tr>
<td>Raw PF Score</td>
<td>2%</td>
</tr>
<tr>
<td>FDGiA Contribution</td>
<td>0.8</td>
</tr>
<tr>
<td>Required Contributions</td>
<td>40.4</td>
</tr>
</tbody>
</table>

**Combined Weel Storage and Ennerdale sluice (14b)**

**Description**

9.17.10 This option entails the combination of two options: construction of a new tidal sluice near Ennerdale (Option 11b) in combination with offline storage in the vicinity of Weel (Option 4f). Refer to the description of each option for further details. In this option combination, the new tidal sluice obeys the operational rules as specified for Option 11b. However, due to the impact of this upon lowering peak water levels experienced in the Weel area, the storage requirements for the proposed offline storage differ from those specified for Option 4f.

9.17.11 From trials involving a range of spill elevations, it is proposed that a 160m section of the eastern bank of the River Hull (between [506697, 438421] and [506639, 438267]) is
lowered to 3.2m AOD to create a spillway entry from the river into the proposed storage area. This specification is the same as that use for Option 4f. Based on this spillway, modelling indicates that a storage capacity of 917,884 m³ is required to contain spill water generated in the period up to and including the fluvial inundation peak in the River Hull system for the critical 1% AEP event.

9.17.12 The preferred location for the storage structure is to the east of River Hull along the river reach south of Weel (refer to Figure 23 of Option 4f). While the required extent of Option 4f was 67.8 ha, for this option combination the required areal extent is reduced to approximately 45ha, such that the storage area can be placed within a suitable sub-area of the extents.

9.17.13 The required storage capacity will be contained between an existing minimum ground elevation in the area of -0.65m AOD and the 3.2m AOD elevation of the spillway entry. An additional “drowned weir” capacity will be provided by embanking the proposed storage area further to 3.45m AOD. This buffer capacity does not provide reduction in peak inundation volume/extent, but provides temporary storage to protect against tidal or secondary fluvial water level peaks which may occur after the storage area is filled to spillway level and before it begins to be drained.

9.17.14 The estimated embankment requirement is for a 3,100m of the basin perimeter to be raised from current ground levels by an average of 2.65m.

9.17.15 As the equilibrium River Hull water level in the vicinity is approximately 2.5m AOD (i.e. approximately 3m above the base elevation of the proposed storage area), the storage area cannot be gravitationally drained into the River Hull. Instead, it is recommended that the storage area is manually emptied via penstock into an existing land drain to the east, and hence into the Holderness Drain, where equilibrium water levels are typically below -1.5m AOD. Landscaping (e.g. excavation of minor internal drainage channels) may be required to ensure all areas within the storage extent are drainable via the proposed penstock. Further landscaping may also be required downstream of the penstock, to establish connection to one of the existing land drains to the east or north (which have estimated invert levels of approximately -0.5 m AOD), and possibly to deepen the receiving drain to facilitate full drainage to -0.65m AOD.

Benefits

9.17.16 The main benefit of this option is reduction in the overall flood inundation volume. Modelling results have identified that the proposed spillway and storage area will reduce peak 1% AEP inundation volumes for the River Hull system by 10%.

9.17.17 By comparison, Option 11b effects a 4% reduction in peak 1% AEP inundation volumes for the River Hull system, while Option 4f achieves an 8% reduction, such that the benefit of this combined option is less than additive.

9.17.18 This option combination is predicted to be less effective in mitigating flood risk than utilising the existing River Hull Tidal Barrier with modified operational rules (Option 11). It is therefore unlikely to be cost effective compared to Option 11, which has a substantially lower capital cost. A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.

Economic summary
The following table summarises the economic appraisal of this option.

### Funding and contributions

Application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. The table below identifies the scale of external contributions required.

<table>
<thead>
<tr>
<th>Option 14b: Offline Storage and New Tidal Sluice</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Cost (£m) 2064</td>
</tr>
<tr>
<td>PV Benefit (£m) 2064</td>
</tr>
<tr>
<td>Raw PF Score</td>
</tr>
<tr>
<td>FDGiA Contribution</td>
</tr>
<tr>
<td>Required Contributions</td>
</tr>
</tbody>
</table>

With an unfavourable partnership funding score and high cost this combination scheme was not taken forward for further consideration.

### Holderness Drain pumping changes and embankments (1c)

Refer to component option reports for further details of each option. In summary, the options considered in this combination are as follows:

a) Option 1b: Increase pumping capacity at East Hull PS (to 22 m³/s) and Great Culvert PS (to 18.2 m³/s). Decommission Tickton PS and replace with orifice and high-flow weir.

b) Option 7b: Raising of low sections of embankment in the Holderness Drain below Great Culvert, as well as the Ganstead Drain tributary.
This option aims to mitigate predicted detriment caused by Option 7b in the Foredyke Stream and its tributaries, particularly in the region between the Lambwath Stream and Kelwell Drain.

It is recommended that the “switch on” levels for the pumps at Great Culvert PS need to be lowered, and this was part of the Option 1c scenario modelling:

- Great Culvert PS 1 has ON level of -2.35m AOD and OFF level of -2.75. The ON level was changed to -2.50m AOD, the OFF level was unchanged.
- Great Culvert PS 2 has ON level of -2.35m AOD and OFF level of -2.55. The ON level was changed to -2.50m AOD, the OFF level was unchanged.
- Great Culvert PS 3 has ON level of -2.35m AOD and OFF level of -2.45. The ON level was effectively changed to -2.45m AOD, the OFF level was unchanged.
- Great Culvert PS 4 has ON level of -1.90m AOD and OFF level of -2.35. The ON level was changed to -2.2m AOD, the OFF level was unchanged.
- The downstream water level criteria for all Great Culvert pumps were also changed, from employing 1.23/1.45m AOD thresholds to 1.33/1.55m AOD thresholds. For example, pump 1 will switch on if upstream levels are greater than -2.35m AOD and downstream levels are less than 1.23m AOD. The pump will stay on as the upstream level falls below -2.35m AOD (so long as the upstream level is above -2.75m AOD) provided downstream water levels are less than 1.45m AOD. Under the proposed solution, the downstream criteria are raised by 0.1 m.
- Other than pump capacities, no changes were made to the East Hull PS pumps.

Further lowering of the switch on levels may indeed yield further improvements in terms of reduced peak water levels for a given return period. However, this comes at increased pump operation costs, so there is probably an economic optimum. This optimum was not examined as part of modelling, but peak water levels with the pump capacity and operation rule changes are substantially lower than they are at present, so there is net betterment to the issue of backup of minor drains. For example, 100yr peak water levels at the Great Culvert inlets are reduced from 0.656m AOD to 0.19m AOD, the Great Culvert Outlets are reduced from 1.62 to 1.55m AOD, and at East Hull it reduces very significantly from 1.5m AOD to 0.19m AOD.

It is imperative that water levels regulated by the Great Culvert and East Hull Pumping Stations are controlled at a level that is 400mm lower than the existing primary control level. This should be through automatic level control; modelling of the Great Culvert Pumping Station shows that this will substantially reduce flood risk. Observations reported to the project team from Crown Estates agent, which is a land owner in the lower Holderness Drain Catchment, report that lateral drains are unable to discharge to the Holderness drain due to an apparent backwater effect. Observations have confirmed that there are "drowned" non-return valves under normal operating conditions. By maintaining control levels 400mm below the existing primary control level, this issue will be mitigated. Crown agents also report that this problem has increased in regularity over the last decade creating significant sustainability issues for its tenant farmers. Whist there is obvious concern for the viability of productive land any such effect will exacerbate poor antecedent conditions which will increase flood risk to residential properties in parts of East Hull.

Benefits

This option is predicted to decrease peak 1% AEP inundation from the Holderness Drain system by 21%, approximately equivalent to Option 1b in isolation. A small
portion of this reduction is predicted to occur upstream of the Tickton PS location, indicating that the proposed replacement of Tickton PS with a flap valve and high-flow weir does not cause a detriment when combined with increased pumping further downstream.

9.17.28 While a substantial portion of the total volume reduction occurs in agricultural lands and greenspace in the Stone Carr area (between Weel and Wawne) and around the Crofts Drain confluence, this option also resolves flood risk (to the 1% AEP level) for high-value urban areas of Bransholme. A spreadsheet detailing predicted 1% AEP inundation volume reduction for each option is presented in Appendix B, while inundation maps for each option are presented in Annex A.

**Costs**

9.17.29 The cost estimates have been drawn up based on quantities which have been calculated from the current preliminary drawings Table 58 is a summary of the cost estimates:

<table>
<thead>
<tr>
<th>Option 1c</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1b</td>
<td>£3,500,000</td>
</tr>
<tr>
<td>Option 7b</td>
<td>£1,780,000</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td><strong>£5,280,000</strong></td>
</tr>
<tr>
<td>60% optimum bias</td>
<td>£3,168,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>£8,448,000</strong></td>
</tr>
</tbody>
</table>

**Economic summary**

9.17.30 The following table summarises the economic appraisal of this option.

<table>
<thead>
<tr>
<th>Option 1c: Holderness Drain Pumping Stations and Raising of Defences (Option 1b + 7b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
</tbody>
</table>

Direct and indirect damages to Agriculture

| PV Damage (£m) | 154.1 |
| PV Benefit (£m) | 0.8 |

**Total**

| Total PV Damage (£m) | 233.4 |
| Total PV Benefit (£m) | 91.0 |
| PV Cost (£m) | 19.8 |
| Benefit Cost Ratio (BCR) | 4.60 |

**Funding and contributions**

9.17.31 The table below shows the application of the Environment Agency’s Partnership Funding Calculator, assuming a benefit period of 50 years (to 2064), indicates the following potential FDGiA contributions for this option. It also identifies the scale of external contributions required.
9.17.32 Subsequent to the workshops, it was requested that an evaluation of the two Environment Agency pumping stations was made. Existing surface water management in the upper River Hull catchment includes the following transfer pumping arrangements:

a) Hempholme PS: 3 no. 0.63 m$^3$/s capacity pumps transferring water from the Roam Drain near Hempholme Bridge into the Mickley Dike immediately upstream of the Bunker Hill flap valves.

b) Wilfholme PS: 4 no. 2.10 m$^3$/s capacity pumps transferring water from the Beverley and Barmston Drain into the River Hull in the vicinity of Wilfholme Bridge.

9.17.33 As part of an assessment of cost and operational rationalisation options, modelling was conducted to assess the magnitude of detriment associated with the removal of each of these pumping stations, in combination and separately. Note that these options do not represent a feasible flood mitigation option by themselves, since they will produce a detriment, but they may be implemented together with other mitigation elements provided these other elements are sufficient to overcome predicted detriment.

9.17.34 Note that both pumping stations are not critical to onward flow in their inlet channels; the Roam Drain continues westwards beyond the Hempholme PS, while the Beverley and Barmston Drain continues southwards beyond the Wilfholme PS. Therefore, removal of either pumping station does not necessitate the construction of any alternative channel or flow control mechanism so, this assessment examines pump removal with no other alteration to the system.

### Impacts

9.17.35 The removal of both pumping stations in combination is predicted to result in a net increase in peak 1% AEP inundation volume of approximately 2.2% (195,734 m$^3$). The removal of Wilfholme PS in isolation increases peak 1% AEP inundation by approximately 148,705 m$^3$, and is therefore responsible for the majority of the combined detriment. The removal of Hempholme PS in isolation produces a very minor (15,398 m$^3$) increase in peak 1% AEP inundation volumes. Note that the calculated individual detriments do not add together to equal the predicted combined detriment; this discrepancy is caused by numerical issues associated with model computation, such that any alteration to the model has the potential to slightly alter model stability, hence alter the time step used in calculations at any point in the simulation, and subsequently alter flux calculations.

9.17.36 Inundation maps of these various modelled options can be found in Annex A, and combined with these the agricultural cost for the 1yr inundation can be determined.
9.17.37 Based on this analysis, it may be considered feasible to decommission Hempholme PS in combination with for example Option 11. The effect of which would reduce operational and maintenance costs whilst, at the same time, achieving a net mitigation of flood risk. However consideration needs to be given to the usage of these pumps as land drainage assets, and to the effect on cost-benefit analysis.

Economic summary

9.17.38 A number of additional options have been assessed to understand their economic impacts. These are assessed as they were key options included within the 2010 River Hull Strategy and they relate to the cessation of pumping and decommissioning of pumping stations at Hempholme and Wilfholme and individually.

9.17.39 Implementation of these options would require investment in the decommissioning of the pumping stations, however, there would be an overall negative cost from reduced maintenance liabilities.

Table 61 - Damages option 15

<table>
<thead>
<tr>
<th>Additional Option 15: Decommissioning of Upper Catchment Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct and indirect damages to Property</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td>Direct and indirect damages to Agriculture</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Total PV Damage (£m)</td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
</tr>
<tr>
<td>PV Cost (£m)</td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
</tr>
</tbody>
</table>

Table 62 - Damages option 15b

<table>
<thead>
<tr>
<th>Additional Option 15b: Decommissioning of Wilfholme PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct and indirect damages to Property</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td>Direct and indirect damages to Agriculture</td>
</tr>
<tr>
<td>PV Damage (£m)</td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Total PV Damage (£m)</td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
</tr>
<tr>
<td>PV Cost (£m)</td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
</tr>
</tbody>
</table>
Comparison

9.17.40 Analysis shows that Options 15, 15b and 15c, result in an increase in damages relative to the Baseline model run (Tables 64 and 65 below). The outcomes appear not to be driven by property damages, as the results would suggest that there is a positive impact on property damages from all three options which is believed to be caused by reduced flood risk in the receiving River Hull.

9.17.41 Instead, the impact is clearly driven by higher agricultural damages, which are particularly high when both pumps are decommissioned. The weighting of capped PV property damages to agricultural damages is fairly equal, which raises a difficult question over the relative merits of protecting properties or agricultural land.

9.17.42 However, overall, switching off both pumps and decommissioning them would cost the nation more than continuing to operate them.

9.17.43 Of the three sub-options there is also a difficult question raised by a positive net present value (NPV) for the decommissioning of Hempholme PS (Option 15c). Whilst there is an increase in overall flood damages of £1.6m, there is also a reduction in operating cost that is of a greater magnitude than the increase in damage (-£2.4m). This option in isolation could provide a saving to the nation of £0.7m over the benefit period of 100 years.

Table 63 - Damages option 15c

<table>
<thead>
<tr>
<th></th>
<th>PV Damage (£m)</th>
<th>PV Benefit (£m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct and indirect damages to Property</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV Damage (£m)</td>
<td>158.7</td>
<td></td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td><strong>Direct and indirect damages to Agriculture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV Damage (£m)</td>
<td>167.2</td>
<td></td>
</tr>
<tr>
<td>PV Benefit (£m)</td>
<td>-12.4</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total PV Damage (£m)</td>
<td>326.0</td>
<td></td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
<td>-1.6</td>
<td></td>
</tr>
<tr>
<td>PV Cost (£m)</td>
<td>-2.4</td>
<td></td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Table 64 - Summary of Option 15 series damages

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PV Damages (£)</th>
<th>PV Damages Avoided (Benefits) (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>£169,478,441</td>
<td></td>
</tr>
<tr>
<td>Op15</td>
<td>£167,740,965</td>
<td>£1,737,476</td>
</tr>
<tr>
<td>Op15b</td>
<td>£157,528,916</td>
<td>£11,949,525</td>
</tr>
<tr>
<td>Op15c</td>
<td>£158,730,725</td>
<td>£10,747,716</td>
</tr>
</tbody>
</table>
In order to address the above quandary a further option has been considered, which represents the refurbishment and refitting of the Hempholme and Wilfholme pumping stations with newer more efficient submersible canister type pumps; these pumps are much more responsive to level control operation with significant reductions in power costs. The stations would also be equipped with new electrical controls and telemetry. The cost of this would be in the region of £1.2m and there would be a maintenance liability of £50,000 per year instead of the £116,000 per year presently. This option would also produce a reduction in maintenance and assuming that damages did not change from those of the Baseline scenario, there would be a positive net present value generated by this reduction in maintenance. However, if the damages did change similar to that from Option 15b or 15c, then this would not be the case.

**Costs**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PV Damages (£)</th>
<th>PV Damages Avoided (Benefits) (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>£154,847,829</td>
<td></td>
</tr>
<tr>
<td>Op15</td>
<td>£193,072,369</td>
<td>-£38,224,541</td>
</tr>
<tr>
<td>Op15b</td>
<td>£169,758,120</td>
<td>-£14,910,291</td>
</tr>
<tr>
<td>Op15c</td>
<td>£167,222,163</td>
<td>-£12,374,334</td>
</tr>
</tbody>
</table>

The capital cost estimates of the refurbished pumping stations are shown below.

Although the use of renewable energy sources, such as wind and solar energy, have become more widespread within the industry, their use is usually limited to low wattage applications, such as telemetry and remote instrumentation. Renewable sources can be used for higher power operation, operating pump motors, however, there is a problem in providing sufficient storage capacity to ensure reliable operation.

The solar power system consists of solar modules, a solar charge controller, rechargeable deep-cycle battery, power converter or inverter and a weather-proof outdoor enclosure. This system is used to collect solar power and store electrical power, and convert the stored power into the correct voltage to operate the telemetry equipment. Solar power has been typically used to power remote telemetry systems, but higher power operation can be undertaken by increasing the number of solar photovoltaic panels used. Solar power has been used to power an “off grid” potable water pumping station within the UK using 10 solar panels, however, increasing the number of panels requires a larger site compound.
Solar Pumping is very specialized job and calls for high technical expertise starting from pump design and selections to installation and commissioning of systems.

Wind pumps have been used to drain and irrigate land and control the level of water levels in wetlands for a number of years. Traditionally the wind pumps were used to directly power a pump to move the water, this allows for robust and economical operations but does not allow for a controlled pumping regime. Modern wind turbines can be used to charge batteries which then power electrical systems such as telemetry systems or pumps, similar to the solar powered systems.

Consultation comments

Consultation was based on retention of the two stations, not their decommissioning. Consultees welcomed the upgrades to the two pumping stations as they have previously criticised their current operational limitations.

SEA analysis, mitigation and enhancement

As renewal works are likely to be entirely within the confines of the present structures, there will be no direct impacts on designated assets arising from this scheme, and it is also unlikely that there will any direct impacts on any known or unknown non-designated assets. Mitigation measures are therefore not currently proposed, although this can only be confirmed once detailed scheme designs are available. If an external renewable energy source, such as wind turbine, is to be introduced, then this would trigger reconsideration of potential effects and mitigation. Management of construction activities is considered to be a key mitigation factor to reduce the risk of pollution. It is recommended that during any detailed design and construction planning that a CEMP be prepared. The SEA does not consider there are any cultural heritage enhancement opportunities that may arise.

Future operational arrangements

Partners have considered the function and operation of the two pumping stations and have agreed to progress work post Strategy adoption. The agreement thus far is as follows:

The Strategy recognises the importance of the above two pumping stations for low order flood events and land drainage purposes making the case for retention of the pumps in one form or another. There are, however, challenges around future operation and maintenance based on their purpose and funding rules.

It is accepted by all that the current pumping stations are unfit for purpose and have nearly reached their useful asset life. This strategy requires further work to explore the benefits and capital funding arrangements that can be put in place to carry out refurbishment /replacement of the above pumping stations. It is recognised that under existing arrangements it will be difficult for the Environment Agency to continue operating these stations.

The Drainage Board’s position is that there is a need to sustain the current arrangements for land drainage and low order flood events, it is accepted that in more sizeable events the system can become overwhelmed and pumping must cease; this view is supported by partners. The Drainage Board will take on the transfer of ownership of these pumping stations on the basis the stations are refurbished/replaced and provided that the following terms are met:
- The transfer of ownership should be cost neutral to the Board as this responsibility currently rests with the Environment Agency. Numerous options could be explored to establish how to put this in place. The cost neutral includes all items such as running costs and provision for future repairs and replacement, supervision, maintenance, insurance etc. Including for costs to cover increasing operating costs and climate change. The Board would further require a mechanism for recovering funding for additional pumping for whatever reasons such as bank failure in the high level carriers and over topping of the River Hull in extreme events.
- The Board would require the transfer of the freehold land along with all rights and access wayleaves for the necessary operation of the stations.
- The Board would seek arrangements in regard to the pumping station to conduct maintenance works both upstream and downstream, for the proper functioning of the station on what is currently ‘main river’.
- The new/refurbished stations should have an installed capacity equivalent to the existing and installed mechanical screens and automated telemetry system compatible with the telemetry system of the York Consortium Boards.

### 9.18 Summary

9.18.1 The following table provides a summary of the option appraisal. Options in green were taken forward to be appraised as an integrated functioning solution in order to show whether the combined strategy benefit equated to the individually modelled schemes.

<table>
<thead>
<tr>
<th>Option</th>
<th>Short Description</th>
<th>Progress</th>
<th>Reason for action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0a</td>
<td>Do nothing</td>
<td>Discounted</td>
<td>Minimal benefit</td>
</tr>
<tr>
<td>0b</td>
<td>Do minimal</td>
<td>Taken forward as <strong>Option H</strong> along with refurbishment/renewal of existing assets.</td>
<td>Always taken forward</td>
</tr>
<tr>
<td>1b:</td>
<td>Increased capacity at pumping stations</td>
<td>Combined with 7b for <strong>Option C</strong></td>
<td>Positive BCR and potentially fundable</td>
</tr>
<tr>
<td>2</td>
<td>Holderness Drain reshaping and widening</td>
<td>Discounted</td>
<td>Little benefit shown</td>
</tr>
<tr>
<td>3b</td>
<td>Offline storage for Holderness Drain</td>
<td>Discounted</td>
<td>Too expensive and little benefit outside immediate location of storage</td>
</tr>
<tr>
<td>4e</td>
<td>Offline storage East of Eske Wetland</td>
<td>Discounted</td>
<td>Too expensive and benefit approximately half that of Option 4f</td>
</tr>
<tr>
<td>4f</td>
<td>Offline storage at Weel</td>
<td>Combined with Option 11 for Option B then discounted.</td>
<td>Discounted</td>
</tr>
<tr>
<td>4g</td>
<td>4f with increased capacity at Waterside PS</td>
<td>Discounted</td>
<td>Little benefit shown</td>
</tr>
<tr>
<td>5</td>
<td>Increased Waterside PS capacity</td>
<td>Discounted</td>
<td>Little benefit shown</td>
</tr>
<tr>
<td>6</td>
<td>Hull maintenance – Dredging and removal of sunken boats</td>
<td>Taken forward as <strong>Option A</strong></td>
<td></td>
</tr>
<tr>
<td>7b</td>
<td>Raising embankments of Holderness Drain</td>
<td>Combined with Option 1b for <strong>Option C</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 67 - List of initial options and their progress explained
<table>
<thead>
<tr>
<th>Option</th>
<th>Short Description</th>
<th>Progress</th>
<th>Reason for discounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>7i</td>
<td>Raising embankments of Beverley and Barmston Drain</td>
<td>Taken forward as <strong>Option E</strong></td>
<td></td>
</tr>
<tr>
<td>8a</td>
<td>Natural Upland Attenuation</td>
<td>Taken forward as <strong>Option G</strong></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Diversion of Holderness Drain</td>
<td>Discounted</td>
<td>Likely to be too expensive and small benefit</td>
</tr>
<tr>
<td>10</td>
<td>Diversion of Upper Hull</td>
<td>Discounted</td>
<td>Likely to be too expensive and small benefit</td>
</tr>
<tr>
<td>11</td>
<td>Alterations to use of Hull Tidal Barrier</td>
<td>Combined with Option 4f for <strong>Option B</strong>. Combination with 4f not considered beneficial. Alternative Options for 11 created – 11a and 11b.</td>
<td>Not considered in combined strategy model, but natural attenuation, should be considered wherever possible</td>
</tr>
<tr>
<td>12</td>
<td>Option 8a with Option 11 and 1b</td>
<td>Discounted</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bransholme SWPS</td>
<td>Taken forward as <strong>Option D</strong></td>
<td></td>
</tr>
<tr>
<td>14a</td>
<td>Option 11 and 4f</td>
<td>Taken forward as <strong>Option B</strong>. Combined Option later considered unbeneficial and discounted.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Removal of Wilholme and Hempholme PS</td>
<td>Taken forward for supplementary analysis.</td>
<td></td>
</tr>
</tbody>
</table>
SECTION 10: STRATEGY APPRAISAL

10.1 The strategy

10.1.1 Options considered in Section 9 were focussed on mitigating fluvial flood risk within the catchment and six of the options were progressed forward to be included in a “combined options” model using the integrated ICM. These six options were:

a) Option 6 - Dredging of the tidally-impacted reaches of the River Hull
b) Option 1c - Bank raising in the Holderness Drain and Ganstead Drain, combined with pump capacity increases at Great Culvert PS and East Hull PS, and replacement of Tickton PS with a passive flap valve and overflow weir
c) Option 13 - Increased Bransholme PS capacity
d) Option 11 and 4f - Altered utilisation of the existing River Hull Tidal Barrier for flood control and creation of offline storage south of Weel
e) Option 7i - Bank raising in the Beverley and Barmston Drain and Western Drain
f) Option 0b - do minimum/ongoing of existing other maintenance

10.1.2 The combined option is predicted to achieve reductions in combined (fluvial, pluvial and network) peak inundation volumes of up to 2.1 million m³ (for the 1% AEP, 75 hour design event), amounting to a 13% reduction in the 15.9 million m³ peak flood volume. For the 10hr critical network flooding event, the combined option is predicted to achieve a 15% (1.4 million m³) overall reduction in the 9.1 million m³ peak flood volume for the 1% AEP event.

Table 68 - Predicted 1% AEP peak combined inundation volumes from all sources, showing the predicted volumetric mitigation benefit of the combined option.

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Existing Condition (m³)</th>
<th>Combined Option (m³)</th>
<th>Reduction (m³)</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% AEP, 75 hr</td>
<td>15,902,171</td>
<td>13,782,516</td>
<td>2,119,655</td>
<td>13%</td>
</tr>
<tr>
<td>1% AEP, 10 hr</td>
<td>9,150,538</td>
<td>7,780,898</td>
<td>1,369,640</td>
<td>15%</td>
</tr>
</tbody>
</table>

The predicted flood volume reduction for the 75 hour event to predicted individual option reductions obtained from fluvial-only modelling, the predicted 2.1 million m³ reduction for the combined option is less than might be expected. While multiple mitigation options enacted within the same river system may interact to produce a less-than-additive benefit, the flood reduction benefits of Option 1c (impacting the Holderness Drain system) and Option 11 (impacting the River Hull system) should be additive in the combined option. Our explanations for this discrepancy between individual and combined option predicted flood volume reductions include:

a) Reduction in fluvial inflows in the integrated model (which applies rainfall to network sub catchments to allow network flooding prediction, and directly to the 2D mesh to mimic pluvial flooding, in addition to fluvial inflows) relative to the fluvial-only model. This will reduce existing condition peak fluvial flood volumes at the same time as additionally accounting for pluvial and network flooding, and hence reduce the volumetric benefit of any given option or combination targeting fluvial flooding.
b) Refinements to bank definitions implemented during the integrated model build, which will impact exact locations/rates of bank overtopping and hence alter existing condition peak fluvioid flood volumes.

c) Minor changes to antecedent condition.

Costs

10.1.4 Table 69 outlines the expected capital and operational expenditure for all six of these Options.

10.1.5 The following table summarises the economic appraisal of the Baseline scenario as modelled using the integrated model. It should be noted that the damages and benefits presented relate to the maximum damages at each property affected by either a 10 hour storm, which is the critical duration of the surface water drainage system within the

<table>
<thead>
<tr>
<th>Option</th>
<th>CAPEX</th>
<th>CAPEX + 60% OB</th>
<th>Annual OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>£ 469,660</td>
<td>£ 751,456</td>
<td>£ 30,000</td>
</tr>
<tr>
<td>1c</td>
<td>£ 5,280,000</td>
<td>£ 8,448,000</td>
<td>£ 173,000</td>
</tr>
<tr>
<td>13</td>
<td>£ 16,000,000</td>
<td>£ 25,600,000</td>
<td></td>
</tr>
<tr>
<td>4f + 11</td>
<td>£ 24,820,000</td>
<td>£ 39,710,000</td>
<td>£ 2,279,000</td>
</tr>
<tr>
<td>7i</td>
<td>£ 3,240,000</td>
<td>£ 5,184,000</td>
<td></td>
</tr>
<tr>
<td>0b</td>
<td></td>
<td>£ 1,090,000</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>£ 49,809,660</td>
<td>£ 79,693,456</td>
<td>£ 3,572,000</td>
</tr>
</tbody>
</table>

Table 69 - Operational and capital cost of the options included in the “combined options” integrated model.

Table 70 - Integrated model damages summary - baseline

<table>
<thead>
<tr>
<th>Baseline</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct and indirect damages to property</td>
<td>PV Damage (£m)</td>
<td>1,029</td>
</tr>
<tr>
<td>Direct and indirect damages to agriculture</td>
<td>PV Damage (£m)</td>
<td>4.5</td>
</tr>
<tr>
<td>Total</td>
<td>Total PV Damage(£m)</td>
<td>1,033</td>
</tr>
</tbody>
</table>

Table 71 - Initial strategy solution economics

<table>
<thead>
<tr>
<th>Proposed Strategy Solution</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct and indirect damages to property</td>
<td>PV Damage (£m)</td>
<td>985</td>
</tr>
<tr>
<td></td>
<td>PV Benefit (£m)</td>
<td>44.1</td>
</tr>
<tr>
<td>Direct and indirect damages to agriculture</td>
<td>PV Damage (£m)</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>PV Benefit (£m)</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>Total PV Damage(£m)</td>
<td>989</td>
</tr>
<tr>
<td>Total PV Benefit (£m)</td>
<td>44.5</td>
<td></td>
</tr>
<tr>
<td>PV Cost (£m)</td>
<td>42.9</td>
<td></td>
</tr>
</tbody>
</table>
City of Hull, or a 75 hour storm, which is the critical duration of the fluvial system.

10.1.6 Analysis of the combined maximum extents and depths indicates that there is a positive NPV available with a BCR that is greater than one. It should be noted that the delivery of all components of the proposed strategy solution can be optimised further in order to reduce the present value of the investments needed, however, it does suggest that overall the combined options are beneficial in terms of flood risk within the River Hull catchment.

10.2 Appraisal summary

10.2.1 By simulating and evaluating flooding benefits to the catchment, calculating cost-benefit ratios and assessing feasibility of costs, the final and recommended strategy includes the Options within the integrated combined model, as well as the implementation of upland natural attenuation (Option 8). These Options are considered worthy of further investigation and funding.

10.3 Comparison of option combinations

10.3.1 The total Present Value (PV) cost for the shortlisted strategy options are detailed below. These costs assume front loading of capital expenditure and continuous and constant operational costs.
10.4 Calculated damages

10.4.1 The total PVD for the short-listed strategy options are detailed in Table 73. The table above indicates that the highest damages are those associated with a Do Nothing scenario, which is to be expected given the large numbers of properties at risk and the fact that the Hull Tidal Surge Barrier is not operating, there is little to no pumping taking place and failure of defences in some locations.

Table 73 - All options Present Value Damages

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PV Damages (£m)</th>
<th>Damages avoided (£m) from Baseline (Future)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Nothing</td>
<td>5,776.7</td>
<td></td>
</tr>
<tr>
<td>Baseline (Existing)</td>
<td>335.9</td>
<td>-11.5</td>
</tr>
<tr>
<td>Baseline (Future)</td>
<td>324.3</td>
<td></td>
</tr>
<tr>
<td>Option 1b</td>
<td>248.2</td>
<td>76.1</td>
</tr>
<tr>
<td>Option 1c</td>
<td>233.4</td>
<td>91.0</td>
</tr>
<tr>
<td>Option 3b</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Option 4e</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Option 4f</td>
<td>314.3</td>
<td>10.1</td>
</tr>
<tr>
<td>Option 6</td>
<td>322.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Option 6b</td>
<td>322.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Option 6c</td>
<td>322.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Option 7b</td>
<td>244.0</td>
<td>80.3</td>
</tr>
<tr>
<td>Option 7i</td>
<td>322.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Option 8a</td>
<td>317.1</td>
<td>7.2</td>
</tr>
<tr>
<td>Option 11</td>
<td>314.1</td>
<td>10.3</td>
</tr>
<tr>
<td>Option 11a</td>
<td>314.1</td>
<td>10.3</td>
</tr>
<tr>
<td>Option 11b</td>
<td>316.7</td>
<td>7.6</td>
</tr>
<tr>
<td>Option 11c</td>
<td>314.1</td>
<td>10.3</td>
</tr>
<tr>
<td>Option 12</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Option 14a</td>
<td>307.5</td>
<td>16.8</td>
</tr>
<tr>
<td>Option 14b</td>
<td>315.5</td>
<td>8.8</td>
</tr>
</tbody>
</table>

10.4.2 The next highest Option by damages incurred is the current Baseline, which includes the presence of sunken boats along the reach through Hull. Options 1b and 7b provide the greatest benefit relative to the future Baseline, excluding Option 1c, which is a combination of those two options. It can be seen from Option 1c that the benefits of Option 1b and 7b together cannot be simply added together.
10.5 Calculated benefit cost ratios

10.5.1 The benefit cost ratio (BCR) for the short-listed strategy options are detailed in Table 74. These are the ratio between the Present Value of Damages Avoided (Benefits) and the Present Value of Costs.

10.5.2 The table indicates that the highest BCR is that associated with the removal of boats from the River Hull, which provides a high benefit for a relatively low capital investment. Relative to a future Baseline scenario where boats have been removed it can be seen that the highest BCR relate to Option 7b. In isolation this provides the greatest benefit, however, it can also be seen that as part of Option 1C, which also incorporates Option 1b, it continues to provide a positive return on investment. Also positive are an iteration of Option 6, Option 8a, and both Option 11 and 11a.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>BCR above Baseline (Existing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Nothing</td>
<td>n/a</td>
</tr>
<tr>
<td>Baseline (Existing)</td>
<td>n/a</td>
</tr>
<tr>
<td>Baseline (Future)</td>
<td>144*</td>
</tr>
<tr>
<td>Option 1b</td>
<td>6.01</td>
</tr>
<tr>
<td>Option 1c</td>
<td>5.98</td>
</tr>
<tr>
<td>Option 3b</td>
<td>-</td>
</tr>
<tr>
<td>Option 4e</td>
<td>n/a</td>
</tr>
<tr>
<td>Option 4f</td>
<td>0.29</td>
</tr>
<tr>
<td>Option 6</td>
<td>0.75</td>
</tr>
<tr>
<td>Option 6b</td>
<td>1.19</td>
</tr>
<tr>
<td>Option 6c</td>
<td>n/a</td>
</tr>
<tr>
<td>Option 7b</td>
<td>31.23</td>
</tr>
<tr>
<td>Option 7i</td>
<td>0.47</td>
</tr>
<tr>
<td>Option 8a</td>
<td>23.86</td>
</tr>
<tr>
<td>Option 11</td>
<td>1.77</td>
</tr>
<tr>
<td>Option 11a</td>
<td>3.56</td>
</tr>
<tr>
<td>Option 11b</td>
<td>0.23</td>
</tr>
<tr>
<td>Option 11c</td>
<td>0.70</td>
</tr>
<tr>
<td>Option 12</td>
<td>-</td>
</tr>
<tr>
<td>Option 14a</td>
<td>0.42</td>
</tr>
<tr>
<td>Option 14b</td>
<td>0.13</td>
</tr>
</tbody>
</table>

* This BCR relates to the Baseline (current) scenario unlike the rest which relate to the Baseline (future) scenario.
10.6 Discussion and conclusion

10.6.1 The comparison of Options has shown that there are substantial potential damages in the Do Nothing Option. Using this as a baseline would have resulted in significant positive benefits across all options and made visibility of the most beneficial options difficult to ascertain.

10.6.2 Relative to a future Baseline, in which sunken boats have been removed, there are a number of options that produce a positive BCR. Of the positive options, Option 7b had the highest ratio and as such is the preferred Option to be taken forward for optimisation. It was also decided to take Option 1b, Option 6, Option 8a, Option 11 and Option 13 forward into development of an optimised solution.

10.6.3 Note that Option 13 has not been appraised in economic terms in isolation within this study, as it is purely a surface water drainage management option that is being solely funded by Yorkshire Water.

10.6.4 The following conclusions can be made from the economic analysis undertaken:

a) There are a number of options which, relative to the baseline scenario, provide a positive impact on flood risk and positive BCRs (1.19 to 31.23) - All of these options have been taken forward into the Integrated ICM model to be tested as a Proposed Strategy Solution that consists of all separate components;

b) Analysis of climate change impacts does not alter the choice of option taken into the integrated model;

c) The cessation of pumping and decommissioning of the pumping stations at Wilfholme and Hempholme increases damages associated with flooding;

d) The increase in damages from these options comes from agricultural damages and not property damage, which is lower;

e) Decommissioning of Hempholme in isolation could be considered to benefit the nation because the reduction in cost exceeds the increase in flood damage, though the benefit is less than £1m over the benefit period of 100 years. Other wider sustainability issues need to be taken into account here. Further detailed analysis that is likely to be required to understand measures of other funders.
11.1 Proposed strategy – Preferred Approach

11.1.1 After the process of creating initial options for reducing flood risk in the catchment, modelling these options and appraising the benefit and damages of each, the final proposed strategy was agreed by the multi-agency project board and confirmed in discussion with the Advisory Board. To refine the initial list of options to this final strategy various aspects were considered: cost-benefit analysis results; the feasibility and viability of carrying out each option; environmental implications; economic implications.

11.1.2 The final proposed strategy is based on the options included in the integrated combined options model with additional options and re-labelled as:


b) Altered utilisation of the existing River Hull Tidal Barrier for flood control. Originally proposed as Option 11 and included in combined options model with Option 4f which was not considered viable. This option currently involves a new tidal barrier at the mouth of the River Hull, downstream of the existing barrier. However plans to design a tidal lock are being considered.

c) Bank raising in the Holderness Drain and Ganstead Drain, combined with pump capacity increases at Great Culvert PS and East Hull PS, and replacement of Tickton PS with a passive flap valves and overflow weir. Originally proposed as Option 7b and Option 1b.

d) Increased pumping capacity at Bransholme pumping station. Originally proposed as Option 13 and a committed scheme funded by YW.

e) Bank raising in the Beverley and Barmston Drain and Western Drain. Originally proposed as Option 7i.

f) New more efficient pumps installed at Hempholme and Wilfholme. Based on additional analysis on Option 15, 15b and 15c, it was recommended that neither are decommissioned but instead are replaced with more modern submersible with similar time/volume capacity to existing pumps.

g) 25% of available upland catchment to undergo small natural flood management projects. Originally proposed as Option 8.

h) Maintain, refurbish and renew existing assets as currently planned. Originally proposed as Do minimum option.

11.2 Costs

11.2.1 Each option was costed individually for construction using the specification of the option and the guideline prices associated with works to be carried out and existing costs provided by the EA. These were then included in a total of costs that included consultancy fees, site investigations, staff costs and others to calculate the capital expenditure expected for the entire option. These costs can be found in each option throughout Section 9 and are also shown in detail in Appendix D. A 60% optimum bias has been included in the total cost as requested by RHAB, however some of these options could have a lower optimum bias, explained later.
11.2.2 These figures in Table 75 are cash costs and it should be noted that these are discounted in Section 9 and represented in present value terms for the partnership funding calculator.

11.2.3 Operational cost was also calculated for each option with the baseline £1,230,200 collated from existing costs of pumping stations and the tidal barrier within the catchment. The average is calculated, due to some options requiring funding every 5 - 10 years instead of annually. These are also summarised in Appendix D.

11.2.4 Table 75 outlines the capital and operational expenditure (CAPEX and OPEX) estimated for the recommended strategy mentioned in Section 10.

Table 75 - Strategy cost summary

<table>
<thead>
<tr>
<th>Option label</th>
<th>Description</th>
<th>CAPEX +60% OB</th>
<th>OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dredging and Re-profiling the river Hull Channel. Including the removal of sunken boats</td>
<td>£751,456</td>
<td>£30,000</td>
</tr>
<tr>
<td>B</td>
<td>Sluicing for Tidal Exclusion using Tidal barrier at River Hull Mouth</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mitre gates*</td>
<td>£13,802,400*</td>
<td>£75,000*</td>
</tr>
<tr>
<td>C</td>
<td>Increased capacity at pumping stations and raising of embankments along Holderness Drain</td>
<td>£8,448,000</td>
<td>£173,000</td>
</tr>
<tr>
<td>D</td>
<td>Bransholme flood mitigation</td>
<td>£16,000,000</td>
<td>-</td>
</tr>
<tr>
<td>E</td>
<td>Raising of embankments along the Beverley and Barmston Drain</td>
<td>£5,184,000</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>Smaller pumps installed at Wilfholme and Hempholme pumping stations</td>
<td>£1,200,000</td>
<td>£50,000</td>
</tr>
<tr>
<td>F</td>
<td>Upland Natural Attenuation – 25% upland assigned.</td>
<td>£372,960</td>
<td>£62,500</td>
</tr>
<tr>
<td>G</td>
<td>Maintenance of existing assets</td>
<td></td>
<td>£1,230,291</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>£45,758,816</td>
<td>£1,620,791</td>
</tr>
</tbody>
</table>

* Mitre gates solution now deemed unnecessary for immediate implementation. Tidal barrier to be utilised until asset expired. Gates are the preferred option thereafter.

11.2.5 This shows the basic proposed strategy, however there are various methods within each option that need to be studied further. For example, variations in sluicing methods for Option 11c, as well as potential for wind powered pumping stations.

11.2.6 An optimum bias of 60% has been calculated for the capital expenditure but due to increased accuracy of the modelled options a lower optimum bias of 60% can also be included in cost evaluations. This figure however has not been used in cost-benefit analysis.
11.3 Economic summary

11.3.1 The economic appraisal has focussed on a whole catchment approach in order to address concerns raised in consultation on the original River Hull Strategy. Many of the other issues raised in the consultation are now addressed by changes to methodologies presented in the MCM2013. Furthermore, the flooding in 2007 within Hull and the East Riding has allowed directly applicable information to be made available on costs that may not have been incorporated in previous assessments. Although no Risk to Life has been included, other costs have been considered as outlined in Section 6.

11.3.2 The following conclusions can be made from the economic analysis undertaken:

a) There are a number of options which, relative to the baseline scenario, provide a positive impact on flood risk and positive BCRs (1.77 to 31.23) - All of these options have been taken forward into the Integrated ICM model to be tested as a Proposed Strategy Solution that consists of six separate components;

b) Analysis of climate change impacts will not alter the choice of option taken into the integrated model;

c) Economic analysis of the combined effect of these components indicates a positive impact on flood risk and an overall positive BCR (1.04);

d) The cessation of pumping and decommissioning of the pumping stations at Wilfholme and Hempholme increases damages associated with flooding;

e) The increase in damages from these options comes from agricultural damages and not property damage, which is lower;

f) Decommissioning of Hempholme in isolation could be considered to benefit the nation because of the reduction in cost exceeds the increase in flood damage, though the benefit is less than £1m over the benefit period of 100 years. When the requirements of other funders are taken into consideration it is likely that this station shall be refurbished and operated in a more efficient way.

11.4 Phasing

11.4.1 The delivery of the proposed strategy will be phased to maximise the reduction in flood risk whilst making the most of the available funding. The current funding cycle remains until and 2021 and it is expected the strategy components are complete at this stage. The River Hull programme team will oversee the delivery ensuring funding bodies and delivery partners are consulted throughout. 11.5 below shows the expected start and finish dates.

11.5 Component delivery and procurement

11.5.1 The table shows which RMA will be responsible for taking strategy components forward. Because of this, the procurement route varies, as each will use their existing contract framework arrangements to obtain consultancy design and project management services. This ensures that quality assurance and competitive market testing are maintained.

<table>
<thead>
<tr>
<th>Component</th>
<th>Project Executive</th>
<th>When</th>
<th>Cost</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredging</td>
<td>ERYC</td>
<td>2016-2017</td>
<td>671k</td>
<td>FDGiA/LGF/LL</td>
</tr>
<tr>
<td>Boat removal</td>
<td>ERYC</td>
<td>2015-2016</td>
<td>80+k</td>
<td>FDGiA/LGF/LL</td>
</tr>
</tbody>
</table>
### Funding

#### 11.6.1

There are a number of indicative sources of funding for this preferred solution. The figure below shows the indicative funding for the strategy components at the present time. These are likely to be subject to change as individual components are developed further and more detail is ascertained.

![Funding Figure]

<table>
<thead>
<tr>
<th>Component</th>
<th>Funding Source</th>
<th>Start Year - End Year</th>
<th>Funding</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>B Tidal barrier</td>
<td>FDGiA</td>
<td>2016 - 2018</td>
<td>13800k</td>
<td></td>
</tr>
<tr>
<td>Gates</td>
<td>FDGiA</td>
<td>2016 - 2018</td>
<td>13800k</td>
<td></td>
</tr>
<tr>
<td>C Drain banks</td>
<td>HCC</td>
<td>2016 - 2018</td>
<td>82000k</td>
<td>FDGiA/LGF</td>
</tr>
<tr>
<td>G Culvert PS</td>
<td>EA</td>
<td>2016 - 2021</td>
<td>82000k</td>
<td>FDGiA/LGF</td>
</tr>
<tr>
<td>E Hull PS</td>
<td>YW</td>
<td>2016 - 2020</td>
<td>82000k</td>
<td>YW</td>
</tr>
<tr>
<td>D Bransholme PS</td>
<td>YW</td>
<td>Completion 2016</td>
<td>16000k</td>
<td>YW</td>
</tr>
<tr>
<td>E Beverley and Barmston and tributaries banks</td>
<td>ERYC</td>
<td>2020 - tbc</td>
<td>5200k</td>
<td>LGF</td>
</tr>
<tr>
<td>F Hempholme PS</td>
<td>ERYC</td>
<td>2016 - 2018</td>
<td>600k</td>
<td>LGF/EA revenue</td>
</tr>
<tr>
<td>Wilholme PS</td>
<td>ERYC</td>
<td>2016 - 2018</td>
<td>600k</td>
<td>LGF/EA revenue</td>
</tr>
<tr>
<td>G Natural Flood Management</td>
<td>YWT</td>
<td>2017 - 2019</td>
<td>372k</td>
<td>LGF, Enviro partner</td>
</tr>
</tbody>
</table>
11.6.2 The only source of national flood defence funding is Defra’s FDGiA (Partnership) funding which is normally administered by the EA through the 2011 Defra’s Outcome Measures Base Approach adjusted through the PF calculator. Application of the PF calculator has been undertaken and the outcome is described below in further detail.

11.6.3 In respect of national flood defence funding the Humber LEP has also negotiated for control over part of the national flooding budget to be devolved to the local area, giving long term certainty over funding and the potential to deliver more by driving efficiencies. This means priorities can be set locally working in partnership with the local authorities and statutory agencies.

11.6.4 As a result of commitments given as part of the Humber Growth Deal (2015 – 2021) a commitment has been given that the Humber LEP “decisions on local priorities and the use of national and locally raised funding allocated to their area”. LEP members are represented on the River Hull Advisory Board who will work with the EA to ensure appropriate and timely decisions are made about the use of National Flood Defence funding for this strategy.

11.6.5 Yorkshire Water has committed to the funding of works to its Bransholme PS. The improvements to Bransholme PS are a component of the overall preferred strategy and work is already underway. The YW funding amounts to £16m to be spent in Y0 and Y1.

11.6.6 In addition to FDGiA and YW funding, there is indicative funding of up to £12m available of the LGF, again through the Humber Local Enterprise Partnership (LEP). This funding is based around the growth opportunities which include encouraging growth in the business, food, and agriculture and visitor economy. Sustainability in these sectors is essential to meet long term economic aspirations.

11.6.7 Further sources include Local Levy funding, amounting to £50,000 for the removal of sunken boats, and other potential sources of public funding such as revenue sources associated with the creation of a Navigation Authority on the River Hull upstream of the Hull City boundary and funding of capital costs associated with refurbishment of Wilfholme PS and Hempholme PS by ERYC and a private company.

11.6.8 Of particular importance is the LGF funding, the timing and availability of which has played an important part in determining the phasing of delivery. The LGF funding must be spent within the first six years of the programme. Equally important has been the effectiveness of the measures proposed, as the aim has been to maximise the benefits as quickly as possible.

11.6.9 There may be a requirement for the assurance systems of both principal accountable bodies (EA and LEP) to be accommodating to meet the aspirations of partnership funding e.g. to ensure aspirations of growth (LEP) are balanced with environmental considerations (Defra) within appropriate timescales.

11.6.10 Funding for Natural Flood Management is explained in the option appraisal. Pilot projects would likely secure some grant funding from other sources.

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11.7 Partnership funding calculator

11.7.1 Defra’s PF calculator has been applied to identify the FDGiA funding available to the scheme. In accordance with guidance on applying the PF Calculator and in deciding on a preferred option, the following process has been followed.

a) The duration of benefits is taken as 100 years, noting that this requires costs to include capital interventions for replacement or capital maintenance of existing structures within the catchment. Further assessments may take a different period into account.

b) PV Whole-Life Benefits amount to £4.788bn. This was derived from defining damages avoided by implementation of the preferred strategy when compared to a conservative estimate of Do Nothing damages from fluvial only model runs. Note, because of modelling constraints a Do Nothing scenario using the full ICM model was not possible. The fluvial only model incorporates all areas at risk from fluvial sources but excludes damages from areas at risk from surface water/sewer flooding only – the Do Nothing damage used is therefore believed to be conservative.

c) Whole-life PV costs of the preferred strategy include estimated capital costs (£47.5m), PV of EA capital works over the next 100 years (£118.4m) and the PV of EA maintenance costs over the next 100 years (£36.7m) based on discounting current annual maintenance costs of approximately £1.23m per year.

d) Confirmed PV Contributions include Local Levy (£48k), YW funding (£15.7m), contributions towards PS refurbishment by ERYC and a private company (£459k). Total confirmed PV contributions = £16.4m.

e) Qualifying benefits in the Before category under OM2 are based on households in each deprivation class and risk classification from the Do Minimum ICM model outputs, whilst the After qualifying benefits are based on the Preferred Strategy ICM model outputs. Again this is conservative and underplays the properties that would be moved from each classification had the after values been compared to before values derived from a Do Nothing scenario.

f) No other qualifying benefits are incorporated:

- The PF calculator utilising the above produces a Raw PF Score of 133% with an Adjusted PF Score of 145%. The PV FDGiA funding that should be available amounts to just under £31.3m, which is sufficient to cover all capital costs in excess of the available confirmed contributions.
- In the event that LGF funding is confirmed (£12m) and additional revenue sources are developed further to the point that they can be recognised in the PF calculator (approx. £850k), then the following adjustments would be made:

11.7.2 Total potential and confirmed PV Contributions = £29.4m

11.7.3 The PF calculator utilising the above produces a Raw PF Score of 133% with an Adjusted PF Score of 156%. The PV FDGiA funding that would be available would fall to just over £18.4m, which would again be sufficient to cover all capital costs in excess of the available contributions.

11.7.4 Noting from the above the lack of an ICM model Do Nothing scenario and outputs, comparison of the Do Minimum benefits from the ICM against the Do Nothing fluvial benefits has been undertaken in the same manner as above to ensure that the Proposed Strategy is the preferred option.
11.7.5 From analysis, the Do Minimum option, i.e. maintain the current level of revenue maintenance without anything other than planned capital maintenance, has higher benefit cost ratio (BCR) than the proposed Do Something option. However, there is a marginally higher net present value (NPV) associated with the Do Something option and a greater than 1 incremental benefit cost ratio (IBCR) indicating that the Do Something option provides additional value for money over the Do Minimum option. As a result it remains the preferred solution.

11.8 Environmental considerations and opportunities

11.8.1 Section 7 above describes the process that has been adopted to prepare an environmental appraisal of the strategy, and confirms that Water Framework Directive and Habitat Regulations assessments have been carried out. Against the proposed options generated for managing flood risk in the catchment in Section 10, we have attempted to give a flavour of the consultation comments received and how we propose to mitigate the effects of the proposed actions where comments or concerns have been raised or where the various assessments have identified the need for such considerations. Separate reports on consultation responses and how they have helped shape the strategy will be produced as separate documents.

11.8.2 Many of the comments received, especially those from environmental groups or statutory consultees have sought a level of assurance or information that cannot easily be provided at strategy level, simply because that level of information can only be provided at detailed project design stage. In order to provide some assurance, the need for a project level Environmental Impact Assessments in support of any planning application or other regulatory approval process to progress an option(s) is recognised, and would both take account of existing environmental constraints and provide the opportunity to explore enhancement of existing or provision of new features. The SEA Addendum Report that accompanies this strategy document has commenced this process, highlighting such opportunities at a ‘high’ level that can be built upon at a project level as the strategy turns toward implementation of specific options. A summary of the SEA’s considerations is given in the sections that follow.

Population

11.8.3 At a strategic level the direct effects of implementation associated with any option is unlikely to be significant. The key effects, and concern, to local communities within the study area are likely to be those that arise from inundation; with particular emphasis upon the effects to property.

11.8.4 No option promoted within the strategy is predicted to give rise to effects that are worse than the baseline prediction. Options B, C, E and G however, all offer a potential beneficial effect through a reduction to the area of inundation. For Option B this minor beneficial effect is notable for a reduction in predicted inundation within the urban area of Hull, adjacent to Stoneferry Road. Options C and G are both predicted to reduce the area of inundation to the north-eastern fringe of Hull, adjacent to the residential suburb of Bransholme. Option E would offer reduced flood risk to the western edge of Dunswell village.

11.8.5 The SEA has identified no alternative or additional solutions that might need to be undertaken, nor any specific mitigation or enhancement measures.

Flora, fauna and biodiversity

11.8.6 The predicted flood risk for all options involves inundation of nationally important designated sites for nature conservation, and flooding adjacent to other nationally
important sites increasing risk of harm through degradation of water quality and introduction of alien species. Consequently Options A – E are predicted to have very similar indirect effects on ecological receptors compared to the baseline and likely to be neutral in each case. Direct effects likely major adverse for Option A if water injected dredging is carried out in the absence of mitigation, and neutral in the long term. Short term effects of other approaches (Options B – E) are considered likely to be neutral both in the short and long term as operations take place outside nationally and internationally important sites.

11.8.7 Option G offers a more sustainable solution in that measures put in place will increase in effectiveness as time goes by aiming to create a coherent suite of habitats along waterways buffering nationally important sites and increasing ecological resilience at a landscape scale. The deliverability of this approach is currently being demonstrated in River Hull Headwaters SSSI. Consequently from a flora, fauna and biodiversity point of view, Option G presents a scenario where direct effects are considered certain to deliver moderate beneficial effects in the short term and certain to accrue major beneficial effects in the long term. Indirect effects are considered likely to be minor beneficial as whilst localised adverse effects commensurate with baseline conditions on SSSI will occur, there will be a degree of amelioration of adverse effects due to reduction in point source pollution and overland flow in River Hull Headwaters SSSI.

11.8.8 The ecological overview identifies that project level EIA should be carried out for most strategy components.

Landscape and land use

11.8.9 Overall the Strategy Options are considered to have a minor impact on the landscape of the River Hull and Holderness Drain catchment.

11.8.10 The raising of drain embankments (RHICS Options C and E) may result in minor short to medium term adverse direct effects on landscape character, largely as a consequence of tree/vegetation loss. Conversely, provided there is no loss of drainage function or restriction on maintenance, new bankside planting could offer enhancement opportunities, especially if banks could be set back. Shelter could also be provided for fish, where they are known to exist in the drains. However, Natural Flood Management attenuation and infiltration features (RHICS Option G) offer the best opportunity for significant long term landscape character enhancement.

11.8.11 Uncertainty remains over specific impacts and mitigation measures that will need to be addressed at project level.

Cultural heritage

11.8.12 The predicted flood risk for all options involves the inundation of several nationally important designated cultural heritage assets, and flooding adjacent to other assets, thus increasing the risk of harm through a combination of factors including erosion, damp and the deposition of silt and other material. However, relatively few known assets will be affected by the various options, compared to the overall populations for the SEA Addendum study area. Options A and E are predicted to have similar direct effects compared to the baseline, although these effects will be on non-designated assets rather than designated ones. Option C is considered to have a higher level of impact due to the proximity of a Scheduled Monument (Swine Castle Hill). Option G is considered to have the greatest potential adverse direct effect, purely because of the areas likely to be involved and the lack of any detailed proposals at this stage. In all cases however, it should be possible to mitigate the adverse effects of all options at the detailed project level.
Although the threat to designated assets is not large, it is undiscovered assets from the valley's 8,000 year long history of settlement (particularly at lower levels) that is more at risk, and is identified as an area where potential finds are likely, both within watercourses and on land. Pre-works archaeological assessments and field surveys, and in-works watching briefs are likely to be required for several components. Our watchwords should be 'expect the unexpected'.

Recreation and amenity

The network of recreation features across the study area is extensive. They form both an essential amenity to local communities and key element of the local economy. It is not considered that implementation of any option would result, at a strategic level, in significant direct effects. The exception to this is Option A where it is considered that dredging and removal of sunken/abandoned vessels would, in combination, improve the River Hull as a recreational and amenity feature. As long as replacement fish shelter is provided where vessels or reedbeds are removed there should be only minor and short term impact on the river's sports fishery. Part of the rationale for using Water Injection Dredging, should it receive regulatory consent, is that it is less harmful to fish than other dredging techniques.

Potential inundation, arising from each option, would create localised effects; with the extent of impact depending upon a number of factors including level of inundation and duration. In comparison to the baseline prediction the effects are largely neutral. Option G may introduce opportunities for landscape diversity that enhance the existing landscape character and, by implication, offer an improved amenity and recreation resource to what is a predominantly rural study area.

Material assets

The importance of major infrastructure, in particular road and rail routes, to a predominantly rural study area has been identified within this Addendum report. The vital role that communication routes play in the economic and social activities of local communities is similarly recognised. Protection of this infrastructure from flood risk is hence a key objective of the RHICS.

Direct effects arising from any option, other than potentially Option B, are unlikely to be significant. The introduction of a new tidal barrier at the mouth of the River Hull would undoubtedly lead to short term disruption of the navigation route during construction, but be tempered by longer term benefits.

The effects of inundation, most notably potential disruption to communication routes, have been identified and assessed. In this respect, compared to the predicted baseline scenario, Options B, C and E all offer beneficial effects. Option B offers enhanced flood risk protection to both a local road and rail links whilst Option C reduces flood risk to a local road. Option E provides a predicted flood risk protection to an important local trunk road, the A1079 (adjacent to Dunswell).

Water

The majority of direct effects on the water environment stem from the construction phase of each proposed option. Most construction work, most notably Option A, could disrupt the pattern of suspended sediment in the water column and pose a risk of water pollution. However, Option G will likely improve the water quality by removing agricultural contaminants through infiltration, and potentially help reduce sediment transfer from land to watercourses. Both help to meet WFD objectives.
Indirect effects may result in poor water quality due to flood water carrying sediment and pollutants from the inundated land and draining back into the River Hull system, mainly via the low level system.

Geomorphology of the water environment will only see impact from Option A which could be considered beneficial for the river channel. Project level assessment of the impact of dredging on river hydrology will be developed.

Environmental objectives

The strategic level environmental assessment of the final RHICS options has enabled identification of potential conflicts, and opportunities, in respect of the stated environmental objectives. We have reviewed the likely effects upon the environmental objectives arising from each option. This differs from the original SEA which at that time only considered each option as elements within a larger strategy; hence was unable to chart the potential effects of single options or make a comparison between options in terms of potential impacts. The latter is considered, in preparation of this Addendum report, to offer more insight into the strategic effects resulting from each option in order to guide the project level design, development and environmental assessment.

Optimisation of climate change

This study has assessed the consequences of climate change on the damages and impacts of flooding for each of the options taken forward to full economic appraisal. The hydraulic modelling has simulated the climate change impacts for the period 2055, 2085 and 2115 for the 1 in 100 (1% AEP) flood event in order to understand the sensitivity of each of the options. FCERM Appraisal Guidance supplementary documentation – Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities – is used to define the consequences of climate change at each of these epochs. The solutions proposed in this strategy are, therefore, intended to be robust to 2115, based on current climate change forecasts. Strategy review will allow the most current nationally agreed climate change forecasts to be considered at that time.

That FCERM-AG supplementary guidance identifies the following change factors for increases in fluvial flows and rainfall intensity as a result of climate change in the Humber river basin district:

<table>
<thead>
<tr>
<th></th>
<th>Total potential change anticipated for the 2020s</th>
<th>Total potential change anticipated for the 2050s</th>
<th>Total potential change anticipated for the 2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Flows</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
</tr>
<tr>
<td>Extreme Rainfall1</td>
<td>5%</td>
<td>10%</td>
<td>20%</td>
</tr>
</tbody>
</table>

NB, these are only applied to small catchments with an area of less than 5km². For catchments larger than this the % increase for river flows is used.

The guidance on sea level rise is slightly different, as the advice is to adopt the increases in sea level associated with the upper confidence band (95 percentile) medium emission projection from the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report. The scientific basis for this recommendation is provided in Annex 3 of the guidance, the values below have been adopted in this study.

<table>
<thead>
<tr>
<th></th>
<th>Sea level rise (mm/yr) up to 2055</th>
<th>Sea level rise (mm/yr) up to 2085</th>
<th>Sea level rise (mm/yr) up to 2115</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Sea Level Rise

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Present Day</th>
<th>2055</th>
<th>2085</th>
<th>2115</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Nothing</td>
<td>£1,288,847,827</td>
<td>£1,955,870,763</td>
<td>£2,259,946,775</td>
<td>£2,481,468,858</td>
</tr>
<tr>
<td>Baseline (Current)</td>
<td>£81,679,319</td>
<td>£104,022,218</td>
<td>£114,900,937</td>
<td>£115,697,500</td>
</tr>
<tr>
<td>Baseline (Future)</td>
<td>£81,808,671</td>
<td>£102,492,047</td>
<td>£116,652,542</td>
<td>£117,711,713</td>
</tr>
<tr>
<td>Option 1b</td>
<td>£51,826,371</td>
<td>£64,258,128</td>
<td>£72,103,029</td>
<td>£83,579,764</td>
</tr>
<tr>
<td>Option 1c</td>
<td>£41,792,083</td>
<td>£60,934,790</td>
<td>£66,441,512</td>
<td>£65,184,689</td>
</tr>
<tr>
<td>Option 4f</td>
<td>£73,776,886</td>
<td>£96,674,973</td>
<td>£113,479,608</td>
<td>£114,407,479</td>
</tr>
<tr>
<td>Option 6</td>
<td>£79,943,849</td>
<td>£101,331,184</td>
<td>£113,273,408</td>
<td>£113,714,762</td>
</tr>
<tr>
<td>Option 6b</td>
<td>£79,943,849</td>
<td>£101,331,184</td>
<td>£113,273,408</td>
<td>£113,714,762</td>
</tr>
<tr>
<td>Option 6c</td>
<td>£79,943,849</td>
<td>£101,331,184</td>
<td>£113,273,408</td>
<td>£113,714,762</td>
</tr>
</tbody>
</table>

11.9.4 The damages for a 1% AEP (1% AEP) event in the present day and in three key future epochs for each option are below.

11.9.5 The sensitivity of the options to climate change impacts is varied but in general the increase in damages (20% to 52%) exceeds the increase in river flows and rainfall intensity by a considerable margin.

11.9.6 Of the options assessed, Option 1c shows the highest increase (146%) in damages by the year 2055. This increase in damages is also highest in the 2085 epoch but drops by the 2115 epochs, though it is still quite high. It will be noted that the total damages for this option are almost the lowest relative to other options and scenarios; therefore, this higher sensitivity to climate change does not indicate that the option be discounted.

11.9.7 Options 1b, 11 and 14a start as the options least sensitive to climate change in the 2055 epoch. By 2115 however the least sensitive options are Option 6, Option 15. The current scenario (2014 Topo) is also one of the least sensitive to climate change by 2115.

11.10 **Measuring the benefits**

11.10.1 The ICM model outputs for the Do Minimum (existing) and the preferred Strategy have been compared across return periods and for both durations independently and combined in order to identify the number of properties at risk and to identify the change in risk to properties as a result of the preferred solution.

11.10.2 The table below presents the current number of properties at risk in each modelled return period for both a 10 hour and 75 hour duration storm event. The difference is presented below indicates the benefit available from the preferred solution.

Table 79 – Estimated damages in future years.
The table below presents the current number of properties at risk in each modelled return period for both a 10 hour and 75 hour duration storm event. The difference is presented below indicates the benefit available from the preferred solution.

### Table 80 - Properties at risk

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Present Day</th>
<th>2055</th>
<th>2085</th>
<th>2115</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 7b</td>
<td>£46,637,152</td>
<td>£61,655,103</td>
<td>£71,888,538</td>
<td>£70,751,852</td>
</tr>
<tr>
<td>Option 7i</td>
<td>£79,814,145</td>
<td>£99,536,282</td>
<td>£118,679,424</td>
<td>£118,740,853</td>
</tr>
<tr>
<td>Option 8a</td>
<td>£76,055,307</td>
<td>£102,518,458</td>
<td>£113,415,265</td>
<td>£114,364,103</td>
</tr>
<tr>
<td>Option 11</td>
<td>£75,828,416</td>
<td>£91,057,838</td>
<td>£106,723,358</td>
<td>£109,619,169</td>
</tr>
<tr>
<td>Option 11a</td>
<td>£75,828,416</td>
<td>£91,057,838</td>
<td>£106,723,358</td>
<td>£109,619,169</td>
</tr>
<tr>
<td>Option 11b</td>
<td>£79,220,854</td>
<td>£98,933,210</td>
<td>£115,245,737</td>
<td>£116,814,685</td>
</tr>
<tr>
<td>Option 11c</td>
<td>£75,828,416</td>
<td>£91,057,838</td>
<td>£106,723,358</td>
<td>£109,619,169</td>
</tr>
<tr>
<td>Option 14a</td>
<td>£72,057,409</td>
<td>£89,433,246</td>
<td>£105,663,877</td>
<td>£109,103,310</td>
</tr>
<tr>
<td>Option 14b</td>
<td>£77,585,392</td>
<td>£98,547,831</td>
<td>£115,021,409</td>
<td>£116,842,579</td>
</tr>
</tbody>
</table>

### Difference - Properties at Risk

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Present Day</th>
<th>2055</th>
<th>2085</th>
<th>2115</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 7b</td>
<td>£46,637,152</td>
<td>£61,655,103</td>
<td>£71,888,538</td>
<td>£70,751,852</td>
</tr>
<tr>
<td>Option 7i</td>
<td>£79,814,145</td>
<td>£99,536,282</td>
<td>£118,679,424</td>
<td>£118,740,853</td>
</tr>
<tr>
<td>Option 8a</td>
<td>£76,055,307</td>
<td>£102,518,458</td>
<td>£113,415,265</td>
<td>£114,364,103</td>
</tr>
<tr>
<td>Option 11</td>
<td>£75,828,416</td>
<td>£91,057,838</td>
<td>£106,723,358</td>
<td>£109,619,169</td>
</tr>
<tr>
<td>Option 11a</td>
<td>£75,828,416</td>
<td>£91,057,838</td>
<td>£106,723,358</td>
<td>£109,619,169</td>
</tr>
<tr>
<td>Option 11b</td>
<td>£79,220,854</td>
<td>£98,933,210</td>
<td>£115,245,737</td>
<td>£116,814,685</td>
</tr>
<tr>
<td>Option 11c</td>
<td>£75,828,416</td>
<td>£91,057,838</td>
<td>£106,723,358</td>
<td>£109,619,169</td>
</tr>
<tr>
<td>Option 14a</td>
<td>£72,057,409</td>
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<td>Option 14b</td>
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<td>£98,547,831</td>
<td>£115,021,409</td>
<td>£116,842,579</td>
</tr>
</tbody>
</table>

### Table 81 - Changes in property flood level

<table>
<thead>
<tr>
<th>Parameter</th>
<th>5yr Return Period</th>
<th>10yr Return Period</th>
<th>50yr Return Period</th>
<th>1% AEP Return Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties at Risk</td>
<td>3,251</td>
<td>5,235</td>
<td>13,435</td>
<td>18,183</td>
</tr>
</tbody>
</table>
### Table 82 - Do nothing vs Preferred Solution damages

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Properties</th>
<th>Agriculture</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Nothing (Fluvial Only model)</td>
<td>£3,465.0m</td>
<td>£2,311.7m</td>
<td>£5,776.7m</td>
</tr>
<tr>
<td>Do Minimum (combined) Damages</td>
<td>£1,028.7m</td>
<td>£171.4m</td>
<td>£1,200.1m</td>
</tr>
<tr>
<td>Preferred Solution (combined) Damages</td>
<td>£984.5m</td>
<td>£170.2m</td>
<td>£1,154.7m</td>
</tr>
<tr>
<td>Damages Avoided relative to Do Nothing (Fluvial)</td>
<td>£2,480.5m</td>
<td>£2,141.5m</td>
<td>£4,622.0</td>
</tr>
<tr>
<td>Damages Avoided relative to Do Something</td>
<td>£44.1m</td>
<td>£0.4m</td>
<td>£44.5m</td>
</tr>
</tbody>
</table>

### 11.10.6 The benefit apportionment approach is as follows:

- PV damages were estimated for all properties within the floodplain under each scenario.
- PV damages were capped as per guidance in the FCERM-AG and the MCM.
- A review was undertaken of the agreed benefit apportionment approach (agreed between EA, ERYC and HCC) and property datasets prepared by ARUP with.
the proportions allocated to different sources of flooding were matched to those properties within the benefit area.

- Benefits were considered to be ‘available’ where the source of flooding was Beverley and Barmston Drain, River Hull or from the Holderness Drain.
- Further exclusions took place to remove any potential overlap with the WADFAS scheme and COPFAS scheme.
- Only ‘Available’ benefits have been shown in data tables.
- Values to be reviewed once full agreement reached.

### 11.11 Monitoring framework

The Strategy’s SEA has developed a monitoring framework against which progress and achievements can be measured. This is reproduced below. Monitoring will require input from all project partners and relevant bodies such as Natural England. This framework requires further development so it can be used to provide monitoring information to other bodies such as project funders. Some data may be reportable on an annual basis, whereas others may take several years to come to fruition or for effects to be measurable. It is envisaged that comprehensive monitoring will be undertaken as part of the strategy review process, which is likely to be on a five-yearly basis.

<table>
<thead>
<tr>
<th>Environmental Objective</th>
<th>Sub-Objective</th>
<th>Indicators</th>
<th>Data Source/ Current Monitoring</th>
<th>Monitoring Responsibility &amp; Timescale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Protection</td>
<td>To protect people and their property from the adverse effects (physical and psychological) of flooding</td>
<td>Numbers of people affected and/or property protected (including duration of flooding) Employment sustained</td>
<td>Register of properties at risk of flooding. Outcome measure targets through projects</td>
<td>Environment Agency/RHICS Project Board: update in line with RHICS reviews</td>
</tr>
<tr>
<td>Wetland Habitats</td>
<td>To avoid damage to designated sites (e.g. SSSIs, SPA, SAC, Ramsar)</td>
<td>Reported levels of impact to designated sites</td>
<td>Condition of River Hull Headwaters and SSSIs as assessed by Natural England</td>
<td>Natural England, with input from EA: updated approx. every 6 years</td>
</tr>
<tr>
<td></td>
<td>To promote favourable condition of River Hull Headwaters SSSI and other hydrologically sensitive designated sites</td>
<td>Reported favourable condition of River Hull Headwaters SSSI and other SSSIs impacted upon by the proposed options</td>
<td>Condition of River Hull Headwaters and SSSIs as assessed by Natural England</td>
<td>Natural England, with input from EA: updated approx. every 6 years</td>
</tr>
<tr>
<td></td>
<td>To increase resilience of wetland habitats</td>
<td>Creation of wetland habitats and buffer zones</td>
<td>Outcome measure targets in respect of habitats</td>
<td>EA annually</td>
</tr>
<tr>
<td></td>
<td>To contribute to relevant UK and</td>
<td>Achievement of BAP targets for</td>
<td>No strategic level monitoring</td>
<td>Natural England/EA: on</td>
</tr>
<tr>
<td>Environmental Objective</td>
<td>Sub-Objective</td>
<td>Indicators</td>
<td>Data Source/ Current Monitoring</td>
<td>Monitoring Responsibility &amp; Timescale</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------</td>
<td>------------</td>
<td>---------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Wilderness</td>
<td>local BAP habitats, species and other relevant important species in line with targets</td>
<td>species and habitats Increase in eel populations</td>
<td>required. Reporting of habitats and species at project level. Existing Eel Management Plan objectives &amp; actions</td>
<td>project by project basis, feedback to RHICS reviews. EA: as per Eel Management Plan</td>
</tr>
<tr>
<td>Environment</td>
<td>To promote a natural self-sustaining fishery (coarse and salmonid)</td>
<td>Species diversity, biomass and recruitment</td>
<td>Fisheries Surveys</td>
<td>EA: update in line with RHICS reviews</td>
</tr>
<tr>
<td>Sustainable Land Use and Landscape</td>
<td>To support/promote land use change that reduces flood risk and promotes improved landscape character</td>
<td>Area of land providing flood risk management benefits or landscape improvement</td>
<td>No strategic level monitoring required. Project level reporting of landscape character and land use changes</td>
<td>RHICS Project Board: in line with strategy updates</td>
</tr>
<tr>
<td>Agriculture</td>
<td>To reduce the vulnerability of high grade/productive agricultural land to flooding</td>
<td>Loss of high grade/productive land from existing agricultural practice</td>
<td>Feedback from farmers, landowners, IDBs, LPAs and relevant partner groups in relation of ongoing land use</td>
<td></td>
</tr>
<tr>
<td>Cultural Heritage</td>
<td>To prevent damage to designated and undesignated assets within the floodplain</td>
<td>Numbers of assets protected from the adverse effects of flooding</td>
<td>No strategic level monitoring required. Project level assessment and reporting</td>
<td>RHICS Project Board: in line with strategy updates</td>
</tr>
<tr>
<td>Tourism and Recreation</td>
<td>To improve local tourism, amenity and recreation opportunities</td>
<td>Area/number of recreational and amenity facilities protected/created</td>
<td>No strategic level monitoring required</td>
<td>RHICS Project Board: in line with strategy updates</td>
</tr>
<tr>
<td>Transport</td>
<td>To prevent adverse impacts of flooding on major communication links to Hull</td>
<td>Length of roads and rail track protected</td>
<td>No strategic level monitoring required. Project level assessment and monitoring</td>
<td>RHICS Project Board: in line with strategy updates</td>
</tr>
</tbody>
</table>
Environmental Objective | Sub-Objective | Indicators | Data Source/ Current Monitoring | Monitoring Responsibility & Timescale
--- | --- | --- | --- | ---
Water Framework Directive | To protect geomorphological features of the river and floodplain and, where possible, provide opportunities for enhancement | Change in geomorphological diversity and increased 'naturalness' | Achievement of Good ecological status or potential. Project level WFD assessment | EA: updated WFD assessment in line with strategy updates

Water Resources | To protect water quantity for abstraction and supply | Water abstractions protected | Issues relating to abstractions highlighted by Yorkshire Water/other abstractors | EA/Yorkshire Water/other abstractors: in line with strategy updates

Climate Change | To reduce vulnerability to the impacts of climate change and ensure flexibility of options | Flexibility to different climate change scenarios | No strategic level monitoring required | RHICS Project Board in line with strategy updates

11.12 Legacy and legal issues

11.12.1 A substantial amount of electronic data has been generated for the strategy. It is 'owned' by all five flood risk authorities. It is vitally important that it is retained for updating and monitoring purposes and for helping model future flood defence or management works by partners, particularly the Environment Agency. At present all data is held by the four consultancies that have contributed towards the strategy. The modelling consultants, Grontmij, are able to retain all data in their client portal at no cost. The RMAs are all able to have secure access to it. ERYC will continue to manage data on behalf of the partners.

11.12.2 At the previous Board meeting three potential legal issues that may have required new or modified legislation were flagged up: the operation rules of the tidal surge barrier; new mitre gates at the mouth of the Hull; and establishing a navigation authority.

- The Environment Agency’s legal team has confirmed that the surge barrier’s operation rules are sufficiently flexible to allow variations in its use, so no legal change is needed
- Mitre gates are only required if additional use of the surge barrier is shown to be detrimental. Partners would still need to promote or propose a new primary legislation if required
- The most appropriate form of navigation authority, and the need for any legislation, will depend on the outcome of specialist advice received.
Boards and sub-boards

11.12.3 In many ways, the production of the full integrated strategy can be regarded as the ‘end of the beginning’ rather than completion of the Board’s and groups’ (Advisory Board, Community Group and Project Group) tasks. Partners consider that as the study move from strategy preparation to implementation and delivery over the next six years or so, there remains a vital role for the Advisory Board in one form or another. Partners have obligations from funders to measure, monitor and report on achievements. This obligation applies to measuring environmental impacts too, foreseen or otherwise. The Community Group has been invaluable in providing local knowledge and experience and challenge to some of the proposals.

11.12.4 There are now obligations on partners to deliver the strategy on behalf of the partnership – a role beyond a single party. In all cases, the Board and groups may want to consider extending their membership, either with permanent places or having the ability to co-opt individuals or organisations as appropriate. The current project board will explore and make recommendations to a reconvened Advisory Board in due course.

11.12.5 In terms of delivering strategy components, there is a need to establish individual project boards or groups now that project leads (organisations) have been identified for each. Both local authorities have engineering and design teams (ERYC Infrastructure and Facilities, and NPS for HCC) that could contribute to delivery. The EA has experienced project teams.

Navigation authority for the River Hull

11.12.6 At present the River Hull between Struncheon Hill Lock (Hempholme) and its mouth at The Deep falls into three parts. The length from Struncheon Hill Lock to the former Aike Beck junction is part of the Driffield Navigation administered by the Driffield Navigation Trust, whilst from The Deep to Ennerdale Bridge the City Council is Navigation Authority. The remaining (centre) section is a "free" river with no navigation authority. It is this middle section in particular that gives rise to identified problems of abandoned vessels, unauthorised bankside structures, and channel restriction.

11.12.7 Even where there is a navigation authority powers are limited. The Kingston upon Hull Act 1984 consolidated several historical navigation and flood risk powers and the City Council has had to serve notices on the owners of land adjoining the River Hull requiring them to carry out works to prevent the overflow of the River Hull. Defence levels are prescribed. The Council has default powers to do the works itself and recover its costs if the landowner does not undertake them as required. The Act gives the City Council some limited control over berthing or mooring, including levying of fees. It is not currently known what powers the Driffield Navigation Trust (DNT) has over moorings or fees.

11.12.8 However, as a main river, the Water Resources Act 1991 (s.109) and associated byelaws gives the Environment Agency powers to require consent for works in, over, under or adjacent to main rivers. There is a fee of £50 per structure (source: ‘Living On The Edge’ – the EA’s guide to riparian owners). The primary purpose is to maintain river flows and protect defences. The Agency has a record of which structures have consent. These powers do not extend to licensing vessels or raising mooring charges. The Agency controls a locked access to the river via a slipway it owns at Weel; access requires temporary purchase of a key.

11.12.9 One option is to form a board to take control of navigation and there is historical precedents for such a board along the River Hull. A Hull and East Yorkshire River
Board was established in 1948, with land drainage, river gauging, fisheries and pollution responsibilities. In 1963 it was replaced by the Yorkshire Ouse and Hull River Authority, which itself was absorbed into the Yorkshire Water Authority in 1974. Regional WAs had responsibility for all aspects of the water environment, including drinking water and sewage. Local authorities nominated and had just over 50% of board governors; the remaining board places were appointed by the relevant Secretaries of State.

11.12.10 It is recommended that a single navigation authority be created for the River from The Deep north to at least Lansford Bridge Mills in Driffield. The DNT should retain sole responsibility for the Driffield Navigation from its junction with the river at Emmotland.

11.12.11 Two options logically present themselves:

a) a newly formed River Hull Board assumes this role
b) a new separate body is created.

11.12.12 If the former option is preferred the Advisory Board could set up a specific sub-board and co-op additional representatives from organisations not currently part of the RHICS process. The Authority’s principal powers would be to control berthing, licence vessels using the river, and maintaining a navigable channel. It would need to levy appropriate fees, with fees being used to maintain the channel. These will need to be clearly defined and avoid overlap with legitimate powers and responsibilities of existing bodies.

11.12.13 Via either option, the navigation authority could contract out the duties to a third party; however, any revenues from charges would have to cover the third party’s costs, and may leave little for future dredging operations. It is not the intention to replace or replicate the role of the East Yorkshire Rivers Trust, which is a voluntary community based body whose aims are to promote beneficial river restoration and management.

11.12.14 The new navigation arrangement may require the making of legislation, and it is recommended that the two local authorities and the EA jointly promote a Bill if necessary. ERYC has agreed to take the lead on this topic to develop a workable solution. External specialist advice will be sought as appropriate.

Changes to River Hull Tidal Surge Barrier operating rules

11.12.15 If the operating rules of the Hull Tidal Barrier are altered to accommodate a Sluicing for Tidal Exclusion mechanism it is essential that sufficient redundancy is built into any solution to ensure the original function of the barrier, in protecting against tidal surges is ensured. This would be a matter for the Environment Agency in consultation with members of any new River Hull Board. Expert engineering and legal advice will be required which should be subject to independent expert peer review. Tidal flooding is the most dangerous type of flooding - as a minimum the status quo for reliability must be maintained. Early findings now suggest that tidal barrier could indeed be used and could carry no additional cost apart from extra power for operation.