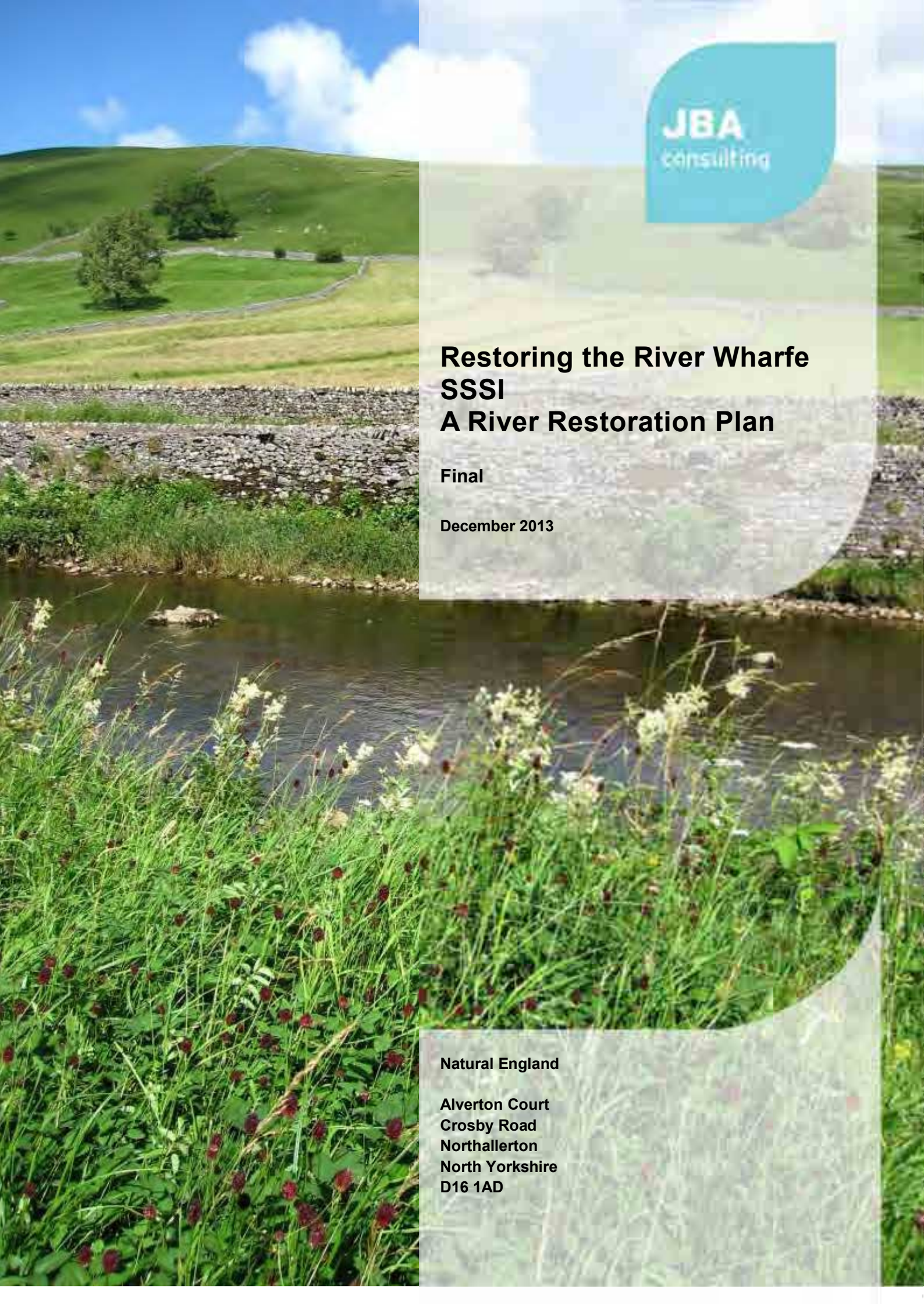

Restoring the River Wharfe SSSI
A River Restoration Plan

Final

December 2013

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Contract

This report describes work commissioned by Natural England, PO 878827. Natural England's representative for the contract was Carole Lowther. George Heritage, Kieran Sheehan, Sebastian Bentley, Matthew Hemsworth and Laura Hicks of JBA Consulting carried out this work.

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Purpose

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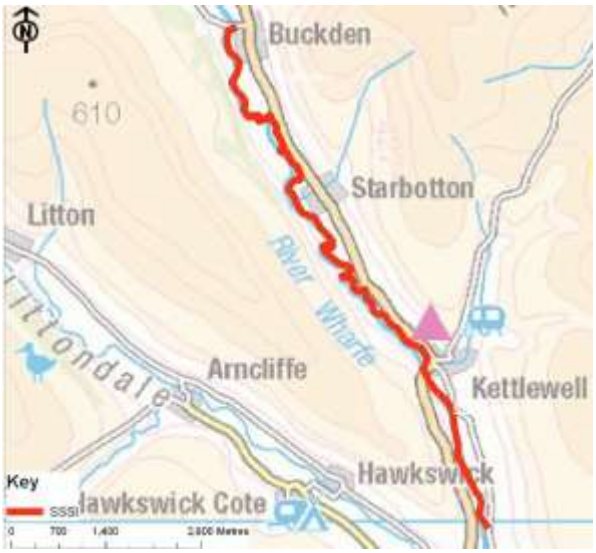
Executive Summary
Restoring the River Wharfe SSSI

Current state of the Wharfe SSSI

The River Wharfe is a nationally important river designated as a Site of Special Scientific Interest (SSSI) for its contrasting upland and lowland character which is important for its wildlife and habitat. The SSSI status covers the river channel and small areas of adjacent floodplain between Buckden and upstream of the River Skirfare confluence near Kettlewell. The River Wharfe is within the protected countryside of the Yorkshire Dales National Park important for its outstanding scenery, wildlife and cultural heritage.



The River Wharfe SSSI
Contains Ordnance Survey data © Crown copyright and database right 2013

View of the River Wharfe downstream of Kettlewell

The River Wharfe SSSI is currently in poor condition as a result of historic management methods which prevent the river from functioning naturally, reducing its ecological health and stopping the SSSI from reaching its potential. The historic management measures include:

- Gravel removal and channel deepening
- Channel realignment
- Construction of flood banks close to the river to protect farmland in the floodplain from periodic inundation
- Construction of walls to reduce natural erosion and restrict natural movement

These alterations prevent the river from functioning naturally, reducing its ecological health and stopping the SSSI from reaching its potential (favourable condition).

Natural England has responsibility, on behalf of government, to oversee the management of all SSSIs that leads to their favourable condition. This requires Natural England to work with SSSI landowners and other stakeholders to improve the condition of unfavourable SSSIs, including the River Wharfe SSSI.

Aims for the River Wharfe SSSI

- To return the river to a near natural condition and ecological health by restoring the rivers natural form and function over the next 50 years.
- To work with local stakeholders to develop a robust river restoration plan which sets out a means by which the recovery of the SSSI can be achieved in the long term.
- To develop a detailed scientific understanding of the river and the options that can restore it to favourable condition.

Species rich meadow adjacent to the river

We hope to achieve the following vision for the River Wharfe SSSI

- A dynamic and diverse river bed which is suitable for fish and invertebrates.
- Variable channel features with a variety of river depths and flow speeds.
- Varied bankside plant structure, including areas of shading and occasional open stretches of floodplain meadow.
- Diverse plant, invertebrate and breeding bird communities that are able to use the river corridor with minimal disturbance.
- Low levels of river engineering allowing natural movement of the channel within a narrow riparian strip.
- Increased connection with the floodplain where wet grassland and meadows, fen, carr and wooded areas may develop.
- Enhance the landscape character's natural beauty, diversity and setting of the river and its floodplain.

Part vegetated gravel bar

Achieving the future vision of the River Wharfe SSSI

In order to achieve our vision there is a need to understand in more detail the morphology and ecology of the river and its floodplain and the processes controlling sediment and gravel redistribution along the system.

We began this process by producing a draft River Restoration Plan. The draft plan laid out a number of restoration options for the river. These options were refined further through a process of public engagement which sought the view of local stakeholders to identify constraints. A Final River Restoration Plan was then produced. This takes into consideration existing constraints and land uses along the river when considering site actions and implementation on the ground.

Site actions in the river restoration plan will be phased over short, medium and long term timescales, up to 50 years, working with local river owners and managers. We will have more detailed discussions about the site-specific actions with relevant stakeholders in the future. Further detailed work and feasibility studies of site specific actions may also be necessary to implement individual actions of the river restoration plan.

How can we deliver restoration?

- Continue positive management of reaches already in good ecological health
- Support and allow the river to recover where natural processes are already working well
- Assist the natural recovery by changing management or by undertaking river restoration works to improve natural channel shape, river processes and ecological habitat
- Remove manmade features where they damage the function of the river whilst recognising the need to protect people and property
- Eradicate non-native invasive riverside plants and undertake a programme of removing them whenever they re-occur
- Working in partnership with river owners and managers

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There are three main documents for the River Wharfe Restoration Plan:

- **Executive Summary:** This sits at the beginning of the non-technical and technical reports and provides a brief high level overview of the River Restoration Plan
- **Non – Technical Summary Report:** This provides a summary of the main technical report.
- **Technical Report:** This is the main report which contains supporting appendices and data.

1 Introduction

1.1 Background

The River Wharfe flowing through Upper Wharfedale is one of England's most active gravel-bed rivers and has a high environmental and amenity value, in the scenic Yorkshire Dales National Park. The River Wharfe is a nationally important river designated as a Site of Special Scientific Interest (SSSI) for its contrasting upland and lowland character important for its wildlife and habitat (Figure 2-1). The SSSI covers the river channel and small areas of adjacent floodplain between Buckden and upstream of River Skirfare confluence. The river is important for several fish species include Brown Trout (*Salmo trutta*) and Grayling (*Thymellus thymellus*). Invertebrate diversity is high and the upper reaches have low vegetation diversity, dominated by mosses and liverworts (*Bryophyta*).

The River Wharfe SSSI is currently in poor condition as a result of historic management. The river has been deepened and embanked in many places which prevents it functioning naturally and restricts its ecological health and overall SSSI condition. It is for these reasons that the river cannot achieve its favourable condition status as a SSSI.

The long term vision and aims for the SSSI are:

- A dynamic and diverse river bed which is suitable for fish and invertebrates.
- Variable channel features with a variety of river depths and flow speeds.
- Varied bankside plant structure, including areas of shading and occasional open stretches of floodplain meadow.
- Diverse plant, invertebrate and breeding bird communities that are able to use the river corridor with minimal disturbance.
- Low levels of river engineering allowing natural movement of the channel within a narrow riparian strip.
- Increased connection with the floodplain where wet grassland and meadows, fen, carr and wooded areas may develop.
- Enhancement of the landscape character's natural beauty, diversity and setting of the river and its floodplain.
- To return the river to a near natural condition and ecological health by restoring the river's natural form and function over the next 50 years.
- To work with local stakeholders to develop a robust river restoration plan which sets out a means by which the recovery of the SSSI can be achieved in the long term.
- To develop a detailed scientific understanding of the river and the options that can restore it to favourable condition.

To achieve this ecological vision a river restoration plan has been developed. This outlines the ecological vision for the naturalisation of the SSSI. The river restoration plan sets out a means by which the recovery of the SSSI can be achieved in the long term. The river restoration plan for the Wharfe SSSI will provide a detailed scientific understanding of the river and lays out a number of restoration options for the river that can restore it to its favourable condition status.

In order to achieve this there is a fundamental requirement to understand in more detail the morphology and ecology of the river and its floodplain and the relationship of this form with the processes controlling sediment and gravel redistribution along the system. Along with an improved scientific understanding of the restoration options, the river restoration plan will take into consideration existing constraints and land uses along the river when considering site based actions and implementation.

The national guidelines for the physical restoration of rivers (Natural England, 2010) identified the need to generate a restoration plan consistent with retaining or moving river SSSIs towards favourable condition. In principle, the vision should advocate whole-river restoration as opposed to ad-hoc, small-scale schemes that are likely to only achieve localised enhancements or assist in small-scale natural recovery processes. The restoration plan should also consider the

potential existing and future impacts from upstream areas, and potential impacts on downstream reaches. It should enable restoration to encourage assisted natural recovery, reducing cost and degree of intervention applied to the river whilst enabling recovery of the habitat to support the characteristic flora and fauna typical of the habitat type to which it was designated.

1.2 Engagement and Consultation

Natural England and the Environment Agency have joint responsibility for developing this River Restoration Plan and for the actions arising from it. A collaborative partnership approach has been taken to develop this plan with others. The Yorkshire Dales Rivers Trust, Yorkshire Dales National Park Authority and National Trust have provided input to help guide and develop the plan.

Natural England and the Environment Agency recognise the challenges, linked to the river, that face land owners and managers throughout the catchment. These include: loss of crops and/or soil due to flood events; maintaining field drainage; reducing nutrient runoff; the availability of water to abstract for summer irrigation. The agencies want to work with farmers to help them deal with these issues while improving and protecting the important river system.

During the development of the Plan the views and concerns of a cross section of stakeholders were sought, including: individual landowners; land managers & farmers; representatives from local communities; relevant public bodies; and delivery partners. Several engagement opportunities have taken place during the development of this plan including letters, newsletters, events and site visits. The comments and information generated through this process have been used to help shape this report. Section 6.1 gives further details.

Future opportunities for more detailed discussions with landowners about specific river reaches will an essential part of developing reach specific restoration projects in the coming years.

1.3 Rationale behind the restoration of SSSI Rivers

SSSIs are the country's very best wildlife and geological sites, they include some of our most spectacular and beautiful habitats. In 2010, 95% of all nationally important wildlife and habitat sites (SSSIs) in England were classed as in, or moving towards, favourable condition. Status review and restoration work is continuing as part of a multi-driver process (including requirements of the Habitats Directive, the Water Framework Directive and Biodiversity Action Plans) and conservation standards have been agreed for assessing the condition of freshwater SSSIs.

Natural England is responsible for notifying SSSIs, ensuring they are managed appropriately and assessing and monitoring their condition. The national guidelines for the physical restoration of rivers that are SSSIs (Natural England, 2010) identified the need to generate a restoration plan consistent with retaining or moving SSSI sites towards favourable condition. In principle, the vision should advocate whole-river restoration as opposed to ad-hoc, small-scale schemes that are likely to only achieve localised enhancements or assist in small-scale natural recovery processes. The restoration plan should also consider the potential existing and future impacts from upstream areas and impacts on downstream reaches. It should also take into account immovable constraints associated with people, infrastructure and the built environment. It should enable restoration to encourage assisted natural recovery reducing cost and degree of intervention applied to the river whilst enabling recovery of the habitat to support the characteristic flora and fauna typical of the habitat type to which it was designated.

The UK conservation agencies set conservation objectives for SSSIs, using agreed national standards, and regularly assess their condition. These objectives are based on the ability of the habitat to support the characteristic flora and fauna of that habitat type, which is considered to be 'Favourable Condition'. Habitat integrity is defined in basic terms by a range of chemical, hydrological and physical targets (some quantitative, some descriptive) considered to represent Favourable Condition.

The latest condition assessment in 2006 for the River Wharfe SSSI found it to be in an unfavourable condition. The SSSI units are not achieving 'favourable' condition for a range of reasons, including physical habitat modifications. As a result, Natural England and the Environment Agency must identify measures to improve the physical condition of the river. An

agreed river restoration plan (i.e. this document) must be prepared and implementation progressed on the ground. This action will contribute to England Biodiversity 2020 Strategy targets for SSSI condition. Additional actions are underway or will be required to address other issues such as pollution and invasive species which affect the River Wharfe SSSI.

This river restoration plan and the progress made to implement opportunities identified will enable the SSSI to recover to a more natural condition. It will be considered to be in an unfavourable recovering condition.

1.4 Aims and objectives

The aim of this project is to appraise the geomorphological condition of the River Wharfe, identifying what the condition of the river is in relation to 'natural' benchmarks, and from this to identify the river restoration, rehabilitation and conservation / enhancement actions that could be put in place to restore the SSSI and bring it into favourable or favourable (recovering) condition (http://www.sssi.naturalengland.org.uk/Special/sssi/search.cfm[1]). This includes the following specific objectives:

- Determine the impacts of physical modifications on the geomorphology and ecology of the river
- Provide an outline restoration plan for the river on a reach by reach basis
- Identify potential delivery mechanisms to help achieve this

The focus of the restoration project is on ensuring the condition of habitats rather than the preservation of species directly, with the principle being that habitats that are characteristic, natural and unconstrained are more likely to support the characteristic flora and fauna.

Although this project is primarily aimed at in-river and riparian characteristics, it is also recognised that the land management adjacent to river channels such as these has the potential to affect the quality of the in-river habitat and as such has been given due consideration throughout this project.

It is also important to note that the term "River Restoration" does not mean returning the rivers to their natural historic course through the valley. The objective is to restore the rivers to a condition such that they can support the biodiversity that is characteristic of their river type, and thereby achieve favourable condition and good ecological status or potential. By addressing the geomorphology, the physical form and functioning of the river, the in-channel features for the river are able to adapt to achieve this more naturally over time.

The Ouse Catchment Flood Management Plan (CFMP) defines the upper Wharfe catchment as an area where flooding can be generated quickly by rapid runoff. The CFMP's vision for this policy area states that action should be taken to reduce flood risk by working with land owners to implement changes to the way land is managed.

1.5 The River Wharfe SSSI

The River Wharfe SSSI extends for 7.1 km between Buckden Bridge and Scargill, just over a kilometre downstream from Kettlewell (Figure 1-1. The SSSI includes the river channel and small areas of adjacent floodplain between Buckden and upstream of River Skirfare confluence (Figure 2-1). The plan also covers small sections of the river up and downstream of the SSSI to ensure sufficient system functioning. The River Wharfe is a nationally important river designated as a Site of Special Scientific Interest (SSSI) for its contrasting upland and lowland river habitat types. The river supports several fish species including Brown Trout (*Salmo trutta*) and Grayling (*Thymellus thymellus*), invertebrate diversity is high, and the upper reaches of the river have generally low vegetation diversity, dominated by mosses and liverworts (*Bryophyta*). The SSSI boundary generally follows the edge of the river, occasionally extending to encompass a narrow strip of floodplain bounded by adjacent flood banks. The majority of the floodplain remains outside of the SSSI. The SSSI is split into three river units all of which were classified as "Unfavourable No Change" in 2006.

[1] Natural England SSSI details (http://www.sssi.naturalengland.org.uk/Special/sssi/search.cfm)

The SSSI starts where the steep river valley begins to open out, occupying a wide infilled glacial valley, and the river switches from a more confined bedrock influenced channel to an active alluvial channel displaying alternating sequences of sinuous single thread and wandering channel types and occasional cobble plane bed channels and bedrock influenced reaches. Flow type and flow energy varies along the SSSI with the river flowing over a diverse morphology composed of gravel, sand and silt (Table 1-1).

The SSSI supports herb-rich grasslands with occasional calcareous flushes. The nationally rare northern spike-rush is present across wet hollows. Tributary streams provide valuable habitat for willow, sedge and rush species. The main river displays a disrupted riparian margin dominated by ash, alder and willow. The river banks support occasional stands of common reed and reed canary-grass.

It is recognised that this study includes an additional 1.5 km of river length up to Hubberholme and 2 km down to the confluence with the Skirfare (Figure 2-1) totalling approximately 10 km of river within the study area of the River Restoration Plan. The plan includes reaches upstream and downstream of the SSSI because the site should not be considered in isolation from the neighbouring reaches.

Figure 1-1 River Wharfe SSSI Unit map

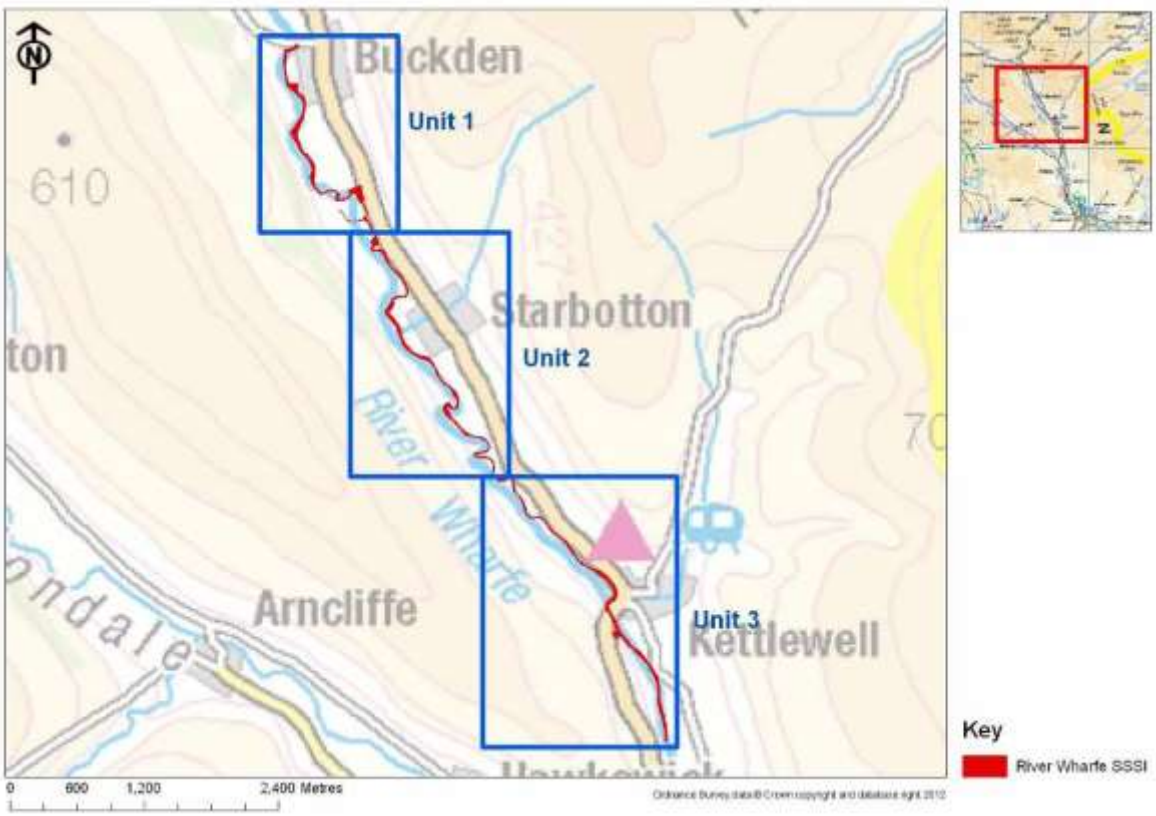


Table 1-1 River Wharfe SSSI river units 2006 condition assessment

SSSI Unit	Present status	Adverse condition
Unit 1	Unfavourable No Change	Inland flood defence works. Bank habitat structure degraded by old and new revetment. Flood banks impact on flood regime and affect bank erosion rates. Species composition not consistent with river type Va*.
Unit 2	Unfavourable No Change	Inland flood defence works. Bank habitat structure degraded by old and new revetment. Flood banks impact on flood regime and affect bank erosion rates. Evidence of river naturalisation in a 'historic realignment channel'. River channel vegetation type Va river has the physical characters of VIIIe.
Unit 3	Unfavourable No Change	Inland flood defence works. Unit fails on all habitat structure. Channel constricted by parallel drystone banking. Fails on species abundance and loss of species targets. Signal crayfish present.
*Note: *The hydromorphological characteristics of river type V (Meso-eutrophic rivers flowing predominantly over sandstone and hard limestone) and river type VIII (oligo-mesotrophic rivers, predominantly upland) are quite similar. Both flow over a coarse bed substrate draining base rich geology with a high proportion of energetic biotopes (riffles and runs). They also display a similar overall channel geometry dominated by shallower narrow to moderately wide cross-sections. Type VIII rivers may be distinguished by more rapid units with coarse cobble and boulder accumulations.*		

1.6 The Water Framework Directive

Objectives set for the Wharfe under the Water Framework Directive are included in the Humber River Basin Management Plan (RBMP). Of particular relevance is that improvements to the condition of the SAC/SSSI are required by both the Habitats Directive and the Water Framework Directive (WFD). A number of measures are included in the RBMP to improve the water bodies to achieve good ecological status or potential (GES/GEP). These measures include further monitoring to confirm reasons for failure for water colour, further investigation into flood risk management and abstraction and also improvements to fish passage. The current status of WFD waterbodies in the study area is given in Table 1.2.

Table 1-2 River Wharfe SSSI current WFD status of relevant waterbodies

SSSI unit	WFD Waterbody	Current WFD status	Reason for failure to achieve GES/GEP
1	Wharfe from Oughtershaw Beck to Park Gill Beck	Good	N/A
2	Wharfe from Park Gill Bk to Barben Beck/River Dibb	Good upstream of Kettlewell Bad downstream of Kettlewell	Fish
3	Wharfe from Park Gill Bk to Barben Beck/River Dibb	Bad	Fish

The standards for WFD Good Ecological Status or Potential (GES/GEP) may be lower than some or all of those for SSSI favourable condition.

1.7 The Vision for the Restoration of the River Wharfe

The River Wharfe Restoration Plan sets out to improve the condition of the river by taking a catchment-scale approach to tackling the factors which contribute to the current unfavourable status of the river.

The plan sets out a long-term, aspirational approach to restoring the natural processes necessary to support the whole-river ecosystem of the Wharfe SSSI river over the next 50 years. This 'process-based' approach will aim to restore natural geomorphic processes and reinstate the natural form and function of the river environment. It is a sustainable approach which allows the river to adapt to future changes so that the benefits of restoration can be maintained with minimal intervention over the long term.

The Plan reflects the range of river types in the catchment, how these have been modified, current land uses and the actions needed to achieve 'favourable condition' of the SSSI. Actions will be designed to assist the natural recovery of the watercourses. Actions will seek to reduce man-made pressures on the river system. They will include removing modifications that are no longer needed and, where appropriate and acceptable, changing in-channel management, improving riparian land management and potentially channel or floodplain restoration.

The rivers directly influence the economic and social well-being of the area and actions to deliver the Plan will take this into account in looking to achieve restoration outcomes. Successful implementation will involve reaching consensus and working with landowners and local communities to develop and implement improvement actions.

The benefits of implementing the River Wharfe Restoration Plan include:

- Improvement of the physical and ecological condition of the SSSI including fish and invertebrate communities, and eventual achievement of favourable condition status.
- Channel activity, morphological diversity and flow regimes which are characteristic of the river types in the catchment and to function as a connected river system.
- A complex mosaic of different habitat types.
- A greater degree of natural channel movement with a reduction in excessive erosion and deposition of sediment.
- Wider understanding and acceptance of how the active river and floodplain system responds more naturally to local and wider catchment processes and events.
- A longer term view of river management which helps landowners plan ahead.
- Opportunities for wider benefits such as reduction in flood risk and soil loss/erosion.
- Provision of supporting evidence for future funding.
- Improved resilience to future changes in the catchment caused by factors such as land use policies and climate change.
- Joint delivery of outcomes required by the Water Framework Directive.

The aims and objectives of this river restoration plan and the progress made to implement opportunities identified will enable the SSSI to recover to a more natural condition to be considered in an unfavourable recovering condition.

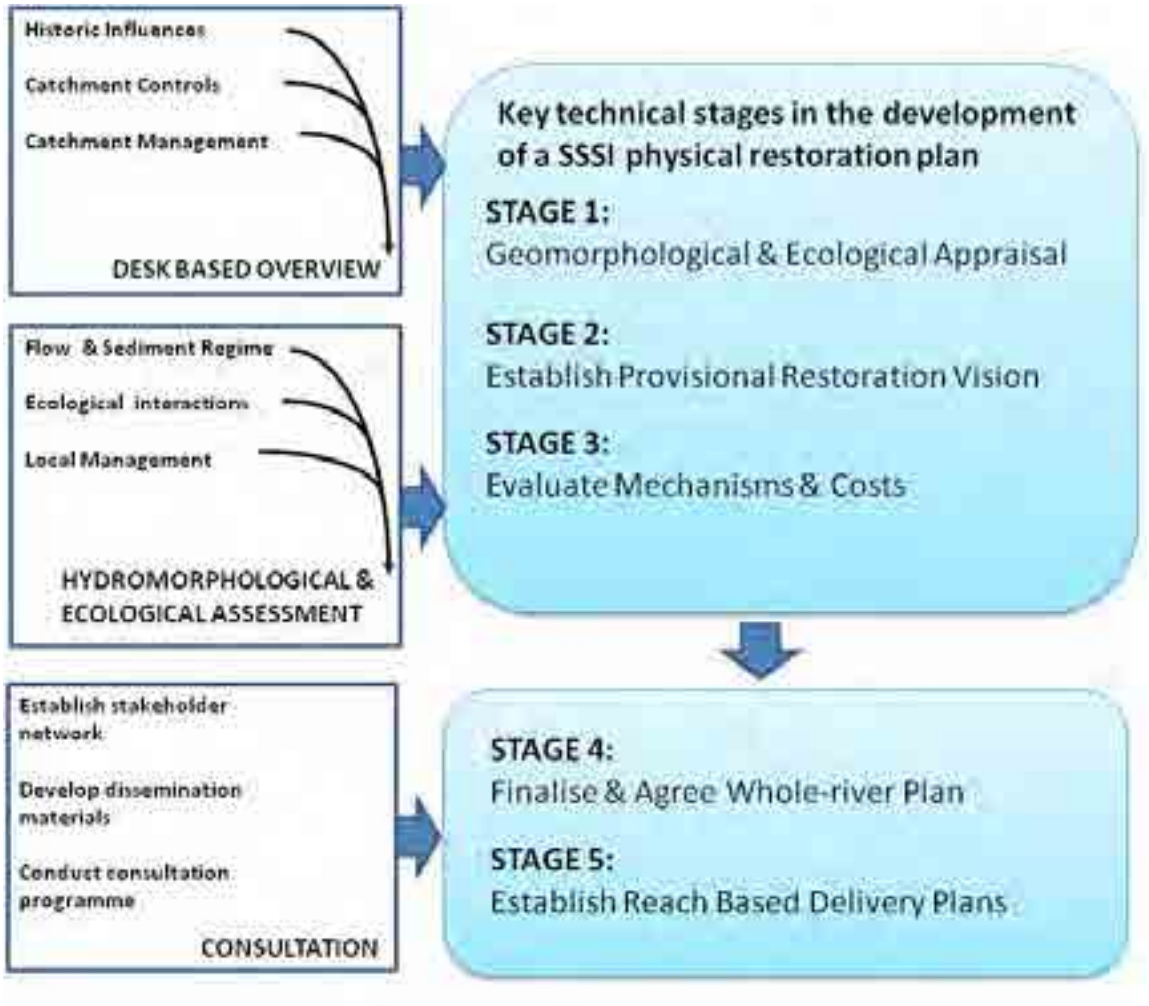
Table 1-3 The Vision for the River Wharfe for the Key River Types

River Type	Vision
Cobble Step Pool 	Channel able to meander & move laterally in its corridor. Channel connected to the floodplain. Minimal incision. Increased stability of banks. Riffle, run, cobble step pool structure. Bed composed of gravels and cobbles. Sensitive flood management & riparian land use. Natural patterns of sediment loading, e.g. from tributaries.
Wandering 	Room for the river- river able to move freely, or freely within a defined “erodible corridor” where constraints exist. Channel connected to the floodplain. Bed of medium/coarse gravel & cobbles. Impacts of former gravel extraction have been mitigated. Natural processes e.g. temporary bars related to flood regime.
Active Single Thread 	Channel able to meander & move laterally in its corridor. Channel connected to the floodplain. Minimal incision. Increased stability of sand/gravel banks. Riffle, run, pool structure. Bed composed of fine gravel / sand. Sensitive flood management & riparian land use. Natural patterns of sediment loading, e.g. from tributaries.
Bedrock Influenced Single Thread 	Channel able to meander & move laterally in its corridor. Channel connected to the floodplain where it is not confined by bedrock. Minimal incision. Increased stability of banks. Riffle, run, cobble step pool structure. Bed composed of gravels and cobbles. Sensitive flood management & riparian land use.

1.8 Project Methodology

The overall approach adopted to generate the restoration plan is summarised in Figure 1-2 and integrates with stages 1 to 4 of the key technical stages required to develop an SSSI physical restoration plan established by Natural England.

Figure 1-2 Project flow diagram for the development of a restoration plan for the River Wharfe SSSI.



1.8.1 Task 1: Desk study

All relevant archive reports on the River Wharfe in the vicinity of the SSSI have been collated from the database held by Natural England, the National Trust, Environment Agency, Yorkshire Dales National Park, and Yorkshire Dales River Trust. These have been reviewed to provide a baseline understanding of the character and functioning of the river and to document historic influences on the system. The JNCC Common Standards Monitoring Guidance for rivers and JNCC river type information for the SSSI have also been utilised to provide guidance on the expected pristine character of the system. Web-based imagery and aerial photography has also been utilised to chart historic planform and morphology change to the river.

Review of existing literature

A review of existing literature on the River Wharfe catchment has been undertaken. The review is summarised below by identifying the key topics of each study. Further detail is included in more detail in Appendix 8.

Table 1-4: Summary of literature review

Author	Date	Title	Key Words
Yorkshire Water	1983	Fisheries Survey of River Wharfe between Hubberholme and Kettlewell	***Fisheries***
Stewart, L	1984	River Wharfe Land Drainage Proposals from above Buckden Bridge down to Kettlewell and their impact on Fisheries and Angling	***Land drainage, Fisheries, Gravel removal***
Urquhart	1987	The ecological condition of the River Wharfe	***Geology, Hydrology, Flow regulation, Grimwith***

Author	Date	Title	Key Words
			Reservoir, Flood alleviation scheme
Yorkshire Water	1987	The ecological condition of the River Wharfe	***Water quality, Ecology, Fisheries***
NRA	1991	Presentation on effects of engineering works on the Wharfe for brown trout	***Fisheries***
Large and Petts	1992	Buffer Zones for Conservation of Rivers and Bankside Habitats	***Buffer zones***
NRA	1995	Post Project Performance Evaluation for the River Wharfe Buckden Scheme	***Flooding, Dredging, Gravel trap***
Arup	1998	Environment Agency Upper Wharfedale Best Practice Project Feasibility Study: Final Report	***Geology, Geomorphology, Hydrology, Ecology, Archaeology, Socio-economics, Upland Grazing, Consultation, Grazing, Restoration, Flood storage***
Heritage and Newson	1998	Dynamic Assessment of the Gravel Trap on the River Wharfe Upstream of Buckden	***Hydromorphology, Gravel trap, Erosion, Sediment transport, Bank protection***
EA	1998	Fisheries Survey of the Upper River Wharfe	***Electro fishing, Fish population***
EA	1998	Fisheries in Upper Wharfedale 1983 to 1998	***Fish population***
Hill and Hack	1999	Upper Wharfedale Best Practice Project River Corridor Survey	***River Corridor Survey, Hydromorphology, Habitats***
Howard et al.	1999	Holocene River Development and Environmental Change in Upper Wharfedale, Yorkshire Dales, England	***Channel change***
ARUP	1999	Upper Wharfedale Best Practice Project – Erosion Risk Assessment	***Gravel Trap, Erosion, Geomorphology***
Unknown	1999	River Corridor Survey	***Hydromorphology, Ecology, Flow regimes***
Arup	1999	Dynamic Assessment of Unstable Reaches of the Upper Wharfe	***Modelling, Hydromorphology, Gravel trap***
JBA	1999	Upper Wharfedale Best Practice Project – Mapping of Moorland Grips and Floodplain Land Use and Conservation Value	***Gripping***
Stewart, L	2000	Report to the Environment Agency Upper Wharfedale Best Practice Project	***Flood alleviation scheme, Gravel trap, Channel stability***
Warren et al.	2000	The distribution of Daubenton's bats and Pipistrelle bats in relation to small-scale variation in riverine habitat	***Ecology***
JBA	2000	Upper Wharfedale Best Practice Project – Hydraulic Modelling, Volumes 1 and 2	***Modelling, Flood banks, Channel alignment***
Haycock Associates	2000	Buckden Gravel Trap River Management Options	***Buckden gravel trap, Hydromorphology***
Lane	2000	Assessment for proposals at Buckden Gravel Trap	***Buckden gravel trap, Hydromorphology***
EA	2000	Upper Wharfedale Best Practice Project Hydrology Report	***Hydrology, Forestry, Gripping***
German and Hill	2001	River Wharfe Geomorphological Audit	***Livestock, Channel change***
EA	2001	Environmental Report on Buckden Gravel Trap Rehabilitation Scheme	***Buckden gravel trap, Hydromorphology***
EA	2002	Upper Wharfedale Best Practice Project. Information series no. 6, River Management Techniques	***River engineering, Gripping, Embankments, Revetment, Buffer strips***

Author	Date	Title	Key Words
Bullen	2002	Upper Wharfedale Vegetation Survey Work	***Habitat, Vegetation, Restoration, Embankment realignment, Fencing***
Reid	2002	GIS based modelling of Coarse Sediment Dynamics within an Upland Gravel-bed River Environment	***Channel change***
Reid	2002	Sediment Delivery, River Dynamics and Ecological Impacts in Upland Floodplains	***Hydrology, Channel change***
McDonald et al.	2003	Information Requirements for the Integrated Management of Agricultural Areas in Sensitive River Basins	***Fine sediment, Catchment management, Gripping, Livestock, Hydrology***
Reid	2003	GIS based modelling of Coarse Sediment Dynamics within an Upland Gravel-bed River Environment	***Sediment delivery***
Unknown	Unknown	River Wharfe Engineering works Photograph collection	***River Engineering, Gravel removal***
Raven et al.	2008	The spatial and temporal patterns of aggradation in a temperate, upland, gravel-bed river	***Sediment delivery, Coarse Sediment***
Hodge et al.	2012	River Wharfe SSSI corridor baseline overview and quantification of substrate movement in Yorkshire Dales National Park	***Sediment delivery, Bank and Bed erosion***
Lane	2012	Impacts of upland open drains upon runoff generation: a numerical assessment of catchment-scale impacts.	***Catchment management, Gripping, Hydrology***

1.8.2 Task 2: Fluvial Audit and modelling

This involved a field and desk based evaluation of the geomorphological nature and dynamics of the River Wharfe looking at local and wider linkages between the form of the river and floodplain and the flow, sediment transport and ecological controls. The audit concentrated on the reach between Hubberholme and the Skirfare confluence, before extending more widely to evaluate the upper catchment and the downstream reach of the River Wharfe. This provides an understanding of wider system influences and ensures that proposed naturalisation options do not adversely impact on the wider river, potentially compromising Water Framework Directive (WFD) objectives. The wider assessment also looked at historic system functioning, legacy engineering and management issues, wider catchment factors and local influences on river system structure and behaviour. Contemporary morphology and processes were audited and mapped alongside the ecology (see below). Near pristine natural sites have been identified and used to determine the optimum geomorphological conditions for the river SSSI. Models of channel behaviour have been developed from the audit findings allowing channel reaction to natural and imposed change factors to be predicted alongside potential ecological response.

1.8.3 Task 3: Ecological survey

The strongest links between the dynamics of the river and floodplain and the habitat mosaic are found at the morphologic unit level and the SSSI displays a wide variety of morphologic units extending beyond the river bank. Naturalisation must consider the process - form - ecology interlinkages across all of these units rather than establishing bankside relationships in isolation. In this way wider improvements can be suggested to the river and floodplain morphology consequently improving overall habitat functioning. A full ecological survey of the bed, banks, bar features and floodplain of the river has been conducted, coinciding with the fluvial audit, to identify the flora and fauna present along the river noting functional relationships between the biota and the morphology. Pristine sites identified by the geomorphological survey were visited and assessed to establish natural vegetation morphology linkages generating an ideal vision of the SSSI ecology under unconstrained geomorphological development conditions.

1.8.4 Task 4: Development of a conceptual model of system function

The approach adopted allows explicit linkages to be made between the ecology, morphology and system controls providing a fully integrated model capable of predicting spatial ecological response to the naturalisation measures determined as appropriate for the SSSI based on the process based hydromorphic assessment and conceptual modelling.

1.8.5 Task 5: Unconstrained approaches to restoration through naturalisation

Given the model of system form and function linked to the detailed morphologic unit scale assessment of the SSSI character, it has been possible to identify appropriate morphologies across the area that will function under the present control conditions and to predict their likely development given natural (climate change) and possible human induced (upland hydrology management) changes.

1.8.6 Task 6: Flood risk and hydraulic assessment

It is recognised that modification to the present physical nature of the river and floodplain (including floodbanks) will impact on flood response and that this will not be confined to the SSSI alone. Extant Environment Agency flow models have been reviewed with respect to the impact of any proposed modifications on key in-channel and floodplain hydraulic components and these will be used to evaluate the broad impacts on flooding at the site and up and downstream. Additionally JBA's in-house 2D distributed flow model JFlow has been run to predict critical flow paths and flood velocities associated with the flooding and to calculate in-channel and floodplain hydraulic parameters important for ecological functioning and sediment transport. These data will demonstrate the potential improvements to hydraulic habitats across the SSSI and will highlight channel and floodplain zones most susceptible to erosion and deposition linked to coarse and fine sediment transport processes. An overview of the hydraulic modelling is provided in Appendix 2.

1.8.7 Task 7: Identification of constraints on naturalisation

A range of options for river and floodplain naturalisation identified in the scoping exercise have been critically reviewed for overall suitability using the dynamic response model. Following this filtering exercise, suitable in-channel and floodplain naturalisation options have been evaluated with regard to the likely morphological response and development, ecological improvements linked to the new geomorphology and the impacts on flooding. This exercise has also considered the wider system response both up and downstream of the SSSI.

In all cases consideration must be given to the current and likely future demands on the area linked to land-use and wider landscape management protocols and in all cases restoration will be linked to contemporary processes to ensure sustainability. Options centred around current process dynamics will facilitate natural recovery but these must be integrated into the wider usage of the river, floodplain and catchment.

The project steering group were involved in the development of the plan and the adoption of the unconstrained vision. The final restoration plan has been developed through meetings with landowners and other interests. Opportunities were provided on several occasions for feedback on the draft plan and the views expressed included within the report where necessary. See section 6 for further details.

1.8.8 Task 8: Reach based action plan

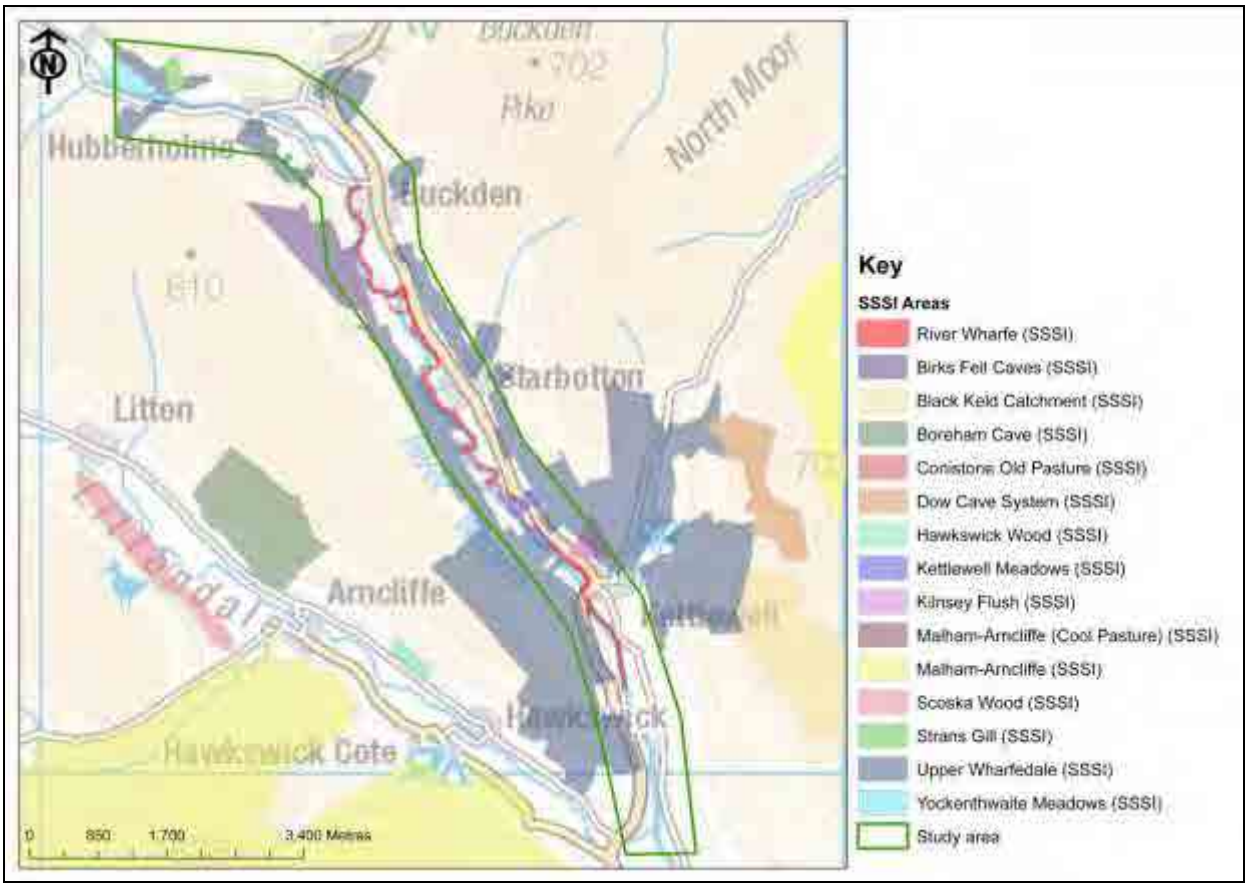
The constrained naturalisation approaches agreed upon following consultation require analysis for economic viability. Costs have been generated and based on previous project costings and supported by EA figures on river works and the SPONS engineering handbook. Following further review of the recommendations by the Steering Group, protocols for delivery and sequencing of the restoration options will be updated to maximise the role of natural system adjustment in achieving the desired restoration objectives.

2 Catchment Overview

2.1 Conditions in the upper catchment

The River Wharfe rises in the region of Pen-y-ghent in North Yorkshire, within the Yorkshire Dales National Park as a series of steep narrow tributary channels of which the principal ones are Oughtershaw Beck and Greenfield Beck in Langstrothdale (Figure 2-1). The catchment of upper Wharfedale receives around 2000mm of precipitation annually and which is rapidly transferred to the main channel along the short confined steep delivery streams. The underlying Carboniferous Limestone and Millstone Grit geology permits sub-surface flow and many of the bedrock influenced tributaries cease flowing at the surface during dry spells.

Figure 2-1 The Upper Wharfe, North Yorkshire.



Upper Wharfedale has many key landscape features such as field meadows dominated by iconic drystone walls and traditional stone field barns. The valley sits amongst an upland landscape of exposed moorland and blanket bog. Rough grazing occurs on the valley slopes whilst permanent pastures can be found on the valley sides and the more fertile valley bottom.

The land use in the upper catchment is dominated by forestry, open moorland grazing and pasture (Figure 2-2). Between the 1960s and 1980s about 17km^2 of moorland was gripped to improve drainage, much of this across Oughtershaw Moss but with significant areas elsewhere in the upper catchment (Figure 2-3). Analysis of time to peak for the Wharfe has shown that flows are reaching their peak more rapidly since gripping (Reid, 2002). However, recent research in the catchment (Lane and Milledge, 2012) suggests that the drying out of the peat in gripped areas is creating increased storage for precipitation and may reduce flood magnitudes and time to peak. It should be noted that Lane and Milledge only focused on the impact on flood risk and time to peak, and not the other environmental problems that gripping can create. Gripping can be beneficial, provided it is strategically planned carefully.

Figure 2-2 Land use in upper Wharfedale.

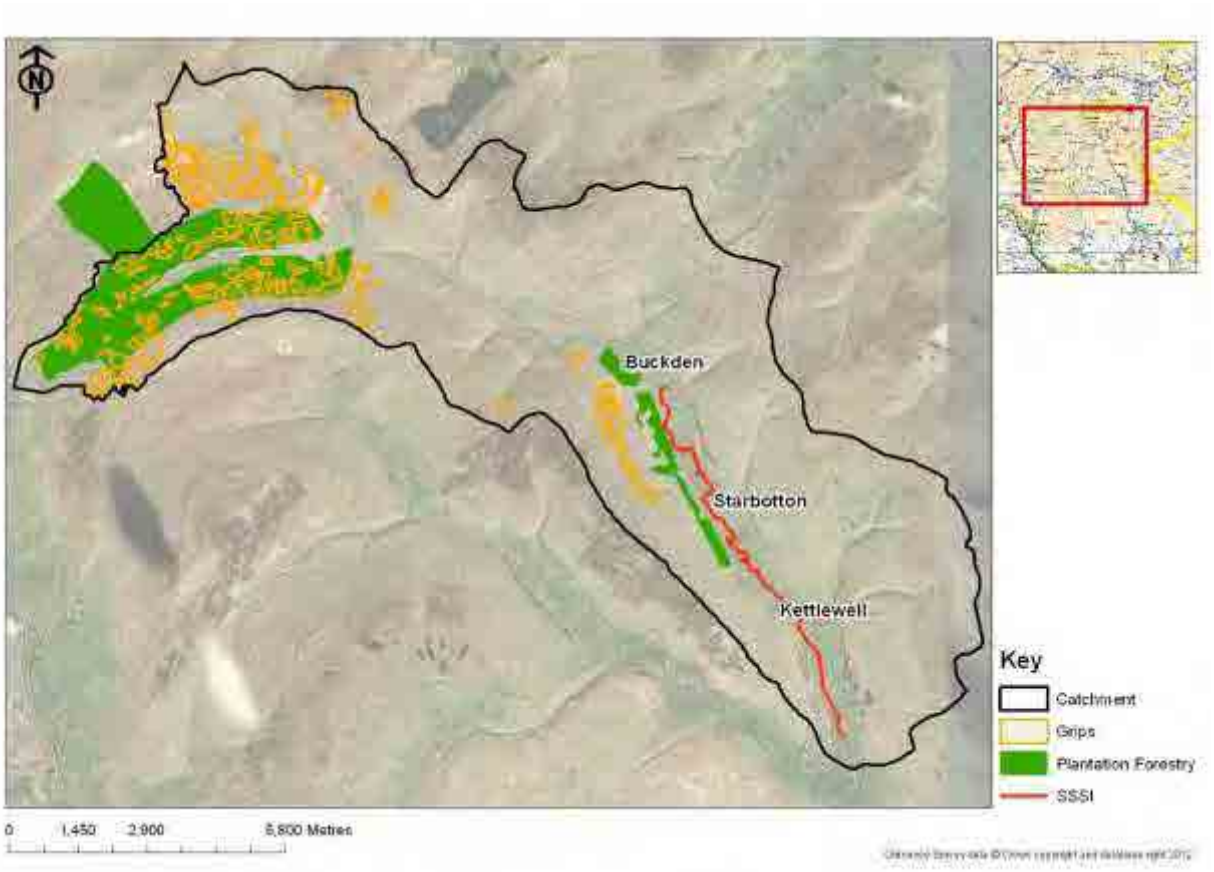
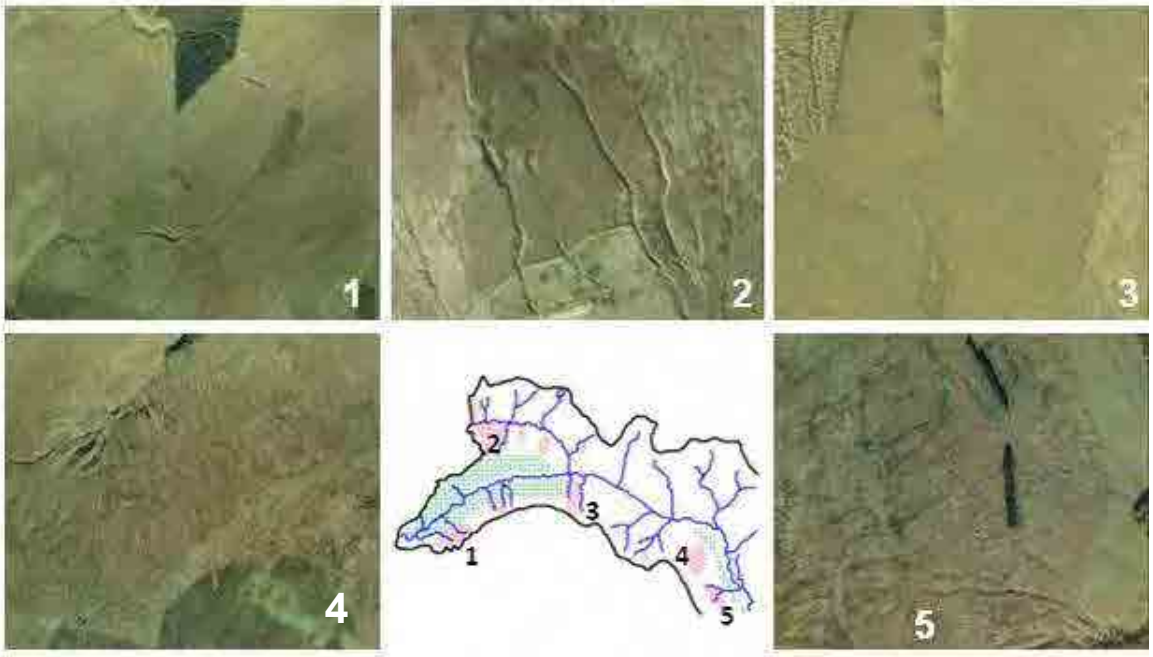


Figure 2-3 Examples of gripping practice in Upper Wharfedale



2.2 Characteristics of the Wharfe tributaries and main channel upstream of the SSSI

The upper catchment is dominated by forestry and moorland, giving way to improved pasture as the floodplain widens downstream of Hubberholme. Generally the landscape is stable, however significant point sources of coarse sediment exist associated with the following conditions:

- Erosion of till deposits along upland gills
- Soil creep processes slowly moving valley side till towards the headwater delivery channels
- Erosion of valley side till with associated downslope transport
- Erosion of previously deposited fluvio-glacial deposits in upland valleys
- Erosion of previously deposited fluvial berms along upland gills
- Direct inputs from scree deposits adjacent to watercourses
- Downstream movement of stored coarse sediment in upland watercourses

The tributary channels of the Upper Wharfe are characterised by a bedrock-dominated morphology (Figure 2-4). They are steep and confined and are capable of efficiently transporting coarse-grained sediment into the main channel during elevated flows. Fine sediment is also generated in the catchment, particularly from forestry activity and diffuse agricultural practices, and may accumulate temporarily in low energy zones along the watercourses. Where these deposits have become vegetated they may be stored for extended periods until a flow of sufficient magnitude occurs to remove the vegetation and associated sediments.

Figure 2-4 Buckden Gill looking up the confined valley. Steep bedrock channel and valley side screes.

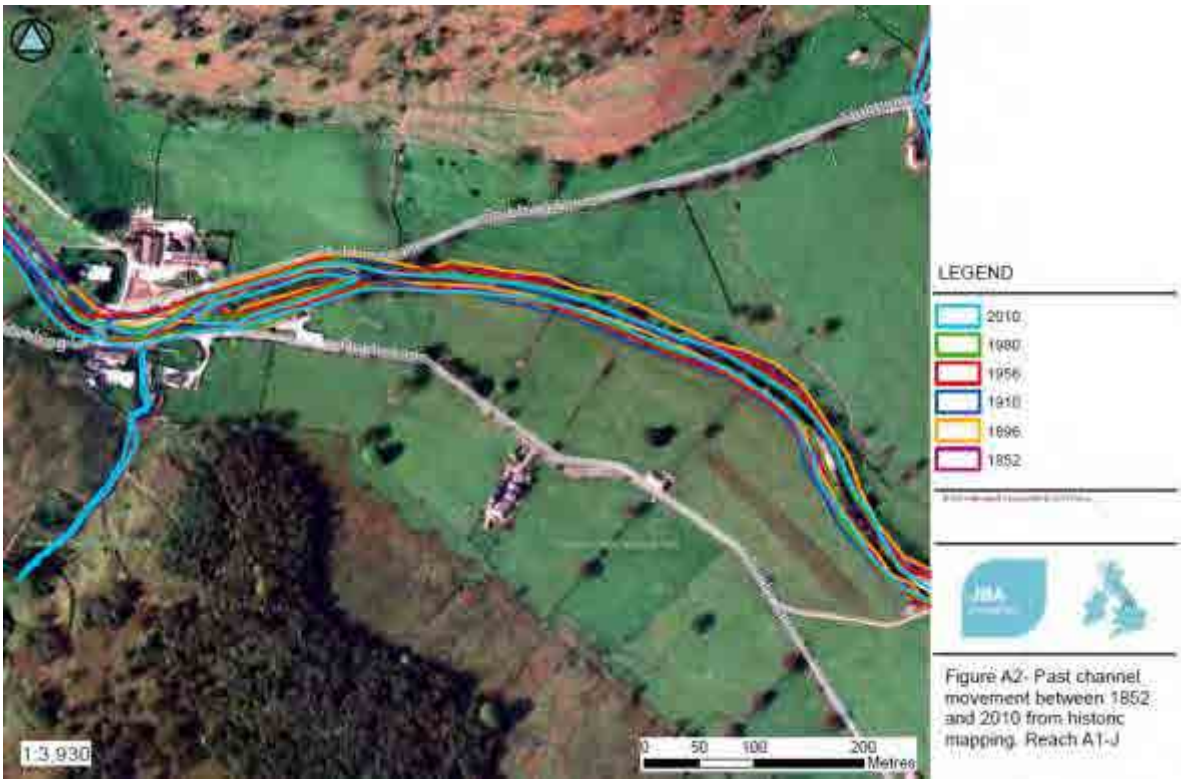
The active delivery of coarse sediment to the main river means that cobble and gravel bar deposits are common after it enters the lower gradient piedmont zone downstream of Hubberholme. Locally these deposits are causing planform instability forming an incipient wandering channel system commonly seen in other rivers in the area. This type of behaviour is a response to the present flow and sediment regime and should be managed for as part of a sustainable approach to dealing with sediment in Upper Wharfedale.

Long term sediment management activities in the upper catchment include de-gripping of moorland areas and planting of headwater gills to help stabilise soil creep processes. However, the volume of sediment currently mobilised within the catchment is large compared with the present size of the bar deposits in the main channel and it is likely that localised sediment source zones will remain active, supplying coarse material to the river, promoting local deposition related erosion in the short and medium term. Longer term channel response to reduced sediment loads is difficult to predict. However, the active high energy nature of the system means that change is inevitable. Sediment starvation generally results in excess energy available to remobilise sediments stored in the channel bed and banks possibly leading to a rationalisation of the channel network within the instability zones, bed lowering and enhanced outer bank erosion. Adjustment to the new sediment regime is likely to be slow and complex due to the continued availability of sediment and the complex hydraulic and morphologic interaction at the local scale.

2.3 Historic Change

A review of the position of the river channel has been undertaken using historic mapping. This is contained within Appendix 9 and shows the degree of channel movement from 1852 to the present day. Limited channel movement has been identified in most areas as it is believed that significant changes to the channel form including channel management began prior to this period.

Figure 2-5 Channel movements at Hubberholme following a review of historic mapping. Further mapping can be found in Appendix 9



3 Reach-scale assessment

3.1 Character of the SSSI

The morphological units of the River Wharfe consist of a valley floodplain and channel features which vary spatially. A distinct switch in character is notable between the headwaters which are characterised by slope instability features, bedrock outcrops and a bedrock / boulder step pool morphology with a generally restricted floodplain and the piedmont SSSI with cobble step pool, active gravel, single thread and wandering river types. These river reaches exhibit pools, glides, riffles, rapids, transverse bars, lateral bars, point bars, eroding banks, and backwaters. Throughout, the diversity of aquatic vegetation within the channel is generally low, with aquatic mosses (Alpine Water-moss *Fontinalis squamosa*, Fountain Feather-moss *Hygroamblystegium tenax* and Brook-side Feather-moss *H. fluviatile*) the only frequent species recorded; although in the more stagnant backwaters diversity is generally increased.

The associated floodplain displays palaeo-channels, floodplain backswamps and levees (natural and man made), which in places provide areas of notable biodiversity interest, with a diverse wetland flora and species of interest, including patches of Northern Spike-rush *Eleocharis austrica*. Historic and contemporary system management means that the majority of the out of channel features are also generally inactive or are evolving very slowly at present, with fluvial geomorphic processes having only a minimal impact on their morphology. This is because the floodplain (currently outside of the SSSI boundary) has suffered major hydraulic and hydrological disconnection from the river displaying only a partial link to river flow processes.

Figure 3-1 Changing characteristics of the Wharfe

3.2 General geomorphological river character

The hydromorphic audit, conducted on the 6th, 7th and 8th July 2012, surveyed the river and floodplain between Hubberholme and the Skirfare confluence. This included a survey of the bed,

banks, bar features and floodplain of the river to identify the existing morphological characteristics, processes sediment sources and sinks, structures, historic channel modifications and the state of the riparian zone. The audit was undertaken by experienced geomorphologists and the features were recorded and photographed using a GPS-based system. The photographs can be seen in Appendix 1, and the hydromorphic audit can be seen in Appendix 5.

3.2.1 Morphology

The River Wharfe through the SSSI is active, moving large amounts of gravel during floods, supplied from abundant floodplain and upper catchment sources. The discharge regime is flashy in nature (as a result of the natural catchment character and precipitation regime and alterations to the hydrology of the upper catchment) and sediment is rapidly mobilised, transported and deposited as river levels rise and fall. Deposition of transported material is controlled by the flood energy and the local river morphology resulting in preferential zones of sediment accumulation within the channel. This pattern of sedimentation and subsequent channel response, whilst creating local bank erosion and loss of floodplain farmland, must be recognised as part of the naturalisation process continually being attempted by the river and such the gravel bar features created are likely to be integral components of a sustainable self-maintaining morphology on the Upper Wharfe. Such zones are common along the river where it begins to flow across a wider floodplain downstream of Hubberholme creating an incipient wandering gravel-bed channel exhibiting a high in-channel geomorphic diversity and associated habitat variety.

3.2.2 Flow Dynamics

Previous survey work (JBA, 2010) notes that gravels within the river are generally deposited in response to local alterations in flow energy, principally caused by the influence of depositional zones downstream. Gravel stalling generates transverse bar features consisting of a major bar deposit towards the centre and margin of one side of the channel and an associated steep low flow channel and downstream riffle unit. Flow direction and flow energy become concentrated, significantly affecting the local morphology, resulting in enhanced potential for bank erosion along one or both banks adjacent to the depositional features and further downstream. These instability zones are then separated by more stable, single thread sections of channel presently acting as transport reaches. This gross morphological form has also been documented by Hodge et al (2012) in their morphological mapping of the river and the importance of gravel stalling influencing channel form is clearly demonstrated by Raven (2008) and the dynamics of these units must be fully understood and integrated into the restoration plan.

Landuse in the upper catchment is dominated by forestry, open moorland grazing and pasture. Between the 1960s and 1980s around 17km^2 of moor was gripped to improve drainage, much of this across Oughtershaw Moss but with significant areas elsewhere in the upper catchment (EA, 2002). Analysis of time to peak for the Wharfe has shown that flows are reaching their peak more rapidly since gripping (EA, 2000). Nevertheless recent research by Lane and Milledge (2012) suggests that the drying out of the peat in gripped areas is creating increased storage for precipitation and may reduce flood magnitudes and time to peak. It should be noted that Lane and Milledge only focused on the impact on flood risk and time to peak, and not the other environmental problems that gripping can create. Gripping can be beneficial, provided it is strategically planned carefully.

3.2.3 Tributary Channels

Tributary channels along the SSSI may be classified into 3 types: longer spatey cobble bed channels draining small catchments extending into headwater areas; shorter alluvial spring fed streams most often with a source on the floodplain; and organic rich small streams and ditches.

Assessments undertaken as part of this plan only cover the lower reaches of the tributaries rather than their full length from their source. Currently the Cray Beck, which flows in to the Wharfe downstream of Hubberholme and Buckden Beck which flows into the Wharfe at Buckden are in good condition. Cam Gill joining the Wharfe at Starbotton exhibits a poor condition between the farm and the river. Kettlewell Beck is degraded and exhibits an armoured cobble bed along with weirs.

3.3 Ecological Baseline

The ecological survey, conducted on the 26th and 27th July and the 14th August 2012, surveyed the river and floodplain between Hubberholme and the Skirfare. This included a survey of the bed, banks, bar features and floodplain of the river to identify the flora and fauna present along the river and functional relationships between the biota and the morphology. The results of the audit are given in Appendix 4.

3.3.1 Floodplain Habitats

The results of the ecological survey were mapped, to Phase 1 Habitat standard, to represent the habitats present along the surveyed section of river. The results of this are shown in Appendix 3, along with descriptions and photographs of the Target Notes.

The dominant habitat along the river is neutral grassland, both unimproved and semi-improved (generally sheep-grazed). There were also relatively significant areas of improved pasture. The unimproved neutral grassland areas were, in general, species-rich, with extensive Meadow Crane's-bill *Geranium pratense,* Meadow Vetchling *Lathyrus pratensis,* Meadow Buttercup *Ranunculus acris,* Meadowsweet *Filipendula ulmaria*, Great Burnet *Sanguisorba officinalis* and in some areas Melancholy Thistle *Cirsium heterophyllum.*

Figure 3-2 Species-rich unimproved neutral grassland south-west of Buckden

Figure 3-3 Species-rich unimproved neutral grassland north-west of Kettlewell

Areas of rushy pasture and marshy grassland were also frequent in the floodplain, particularly in the upstream reaches, upstream of Kettlewell. These areas are often associated with palaeo-features, springs and tributaries of the Wharfe. This habitat type covers a range of marshy grassland habitat types, including areas dominated by sedges (predominantly Lesser Pond-sedge *Carex acutiformis* and Bottle Sedge *Carex rostrata*), wet rushy pastures dominated by Soft Rush *Juncus effusus* and Tufted Hair-grass *Deschampsia cespitosa* and Meadowsweet dominated areas. Within these wetter areas there are often palaeo-features, such as cut-off meanders and palaeo-channels that add floristic interest and habitat diversity to these areas of marshy grassland by providing open water pools, slowly flowing water and ephemeral ponds.

Much of the river length is lined with mature Ash *Fraxinus excelsior* and Sycamore *Acer pseudoplatanus* dominated woodland, with Alder *Alnus glutinosa* also abundant, which creates considerable shading of the channel in places. Crack Willow *Salix fragilis*, Almond Willow *S. triandra*, Grey Willow *S. Cinerea* and Wych Elm *Ulmus glabra* were also present.

3.3.2 In-channel Vegetation

Approximately every 500m along the surveyed reach, grapnel throws were undertaken to record in-channel vegetation. Photographs were also taken across the channel and up and downstream; the results of this are given in Appendix 4. Aquatic vegetation within the channel is generally low, with aquatic mosses (Alpine Water-moss, Fountain Feather-moss and Brook-side Feather-moss) the only frequent species recorded; although in the more stagnant backwaters diversity generally increased.

During the survey, one patch of Northern Spike-rush *Eleocharis austriaca* was recorded, approximately 700m south of Starbotton. All other specimens of spike-rush noted along the river were found to be Common Spike-rush *Eleocharis palustris*. Also, around Kettlewell the Yorkshire Dales National Park have a record of Flat Sedge *Blysmus compressus* and in meadows both up and downstream of Starbotton, although set back from the river itself, there are records of Northern Hawk's-beard *Crepis mollis*.

3.3.3 Protected Species

Otter activity was found to be particularly extensive along the surveyed reach, with a number of spraints, footprints and feeding remains noted. The feeding remains found were exclusively of crayfish. Otter activity was particularly of note to the south of Starbotton, where a number of signs of activity were noted. No holts were recorded during the survey, however, the extensive woodland habitats and rocky banksides provide ample opportunity for Otter resting places. The location of recorded Otter activity is shown in Appendix 7, along with records of non-native, invasive plant species.

3.3.4 Non-native Invasive Species

North American Signal Crayfish *Pacifastacus leniusculus* remains (likely Otter feeding remains) were found in several locations throughout the surveyed reach, indicating a potentially large non-native crayfish population within the river; it is assumed this species is present throughout the surveyed reach and potentially several of the major tributaries. Four live animals were also observed within the river around Starbotton bridge.

One patch of Japanese Knotweed *Fallopia japonica* was recorded approximately 10m upstream of the confluence of Buckden Beck with the River Wharfe. Three individual plants were present on the right bank. Just upstream of Kettlewell, on the left bank, a relatively extensive patch of Himalayan Balsam *Impatiens glandulifera* was recorded. Three much smaller patches were also recorded adjacent to the road a few metres downstream of the more extensive patch. No further occurrences of this species were noted downstream of this occurrence. The above two species are listed on Schedule 9 of the Wildlife and Countryside Act 1981 (as amended) making it an offence to plant these species or cause them to spread in the wild. The non-native Monkey flower *Mimulus guttatus* was also recorded in several places along the river, although not listed on Schedule 9, it is an introduced species.

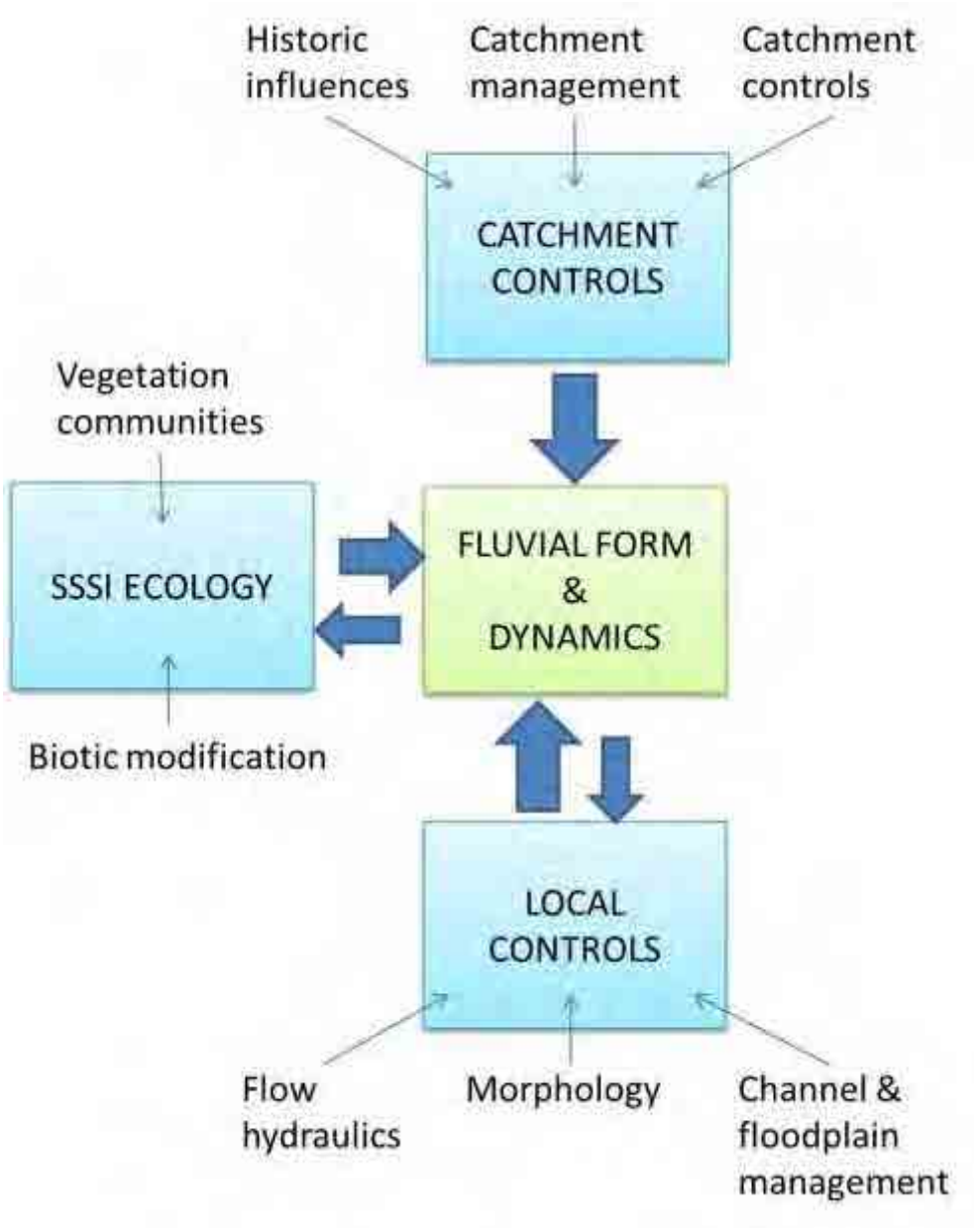
3.4 General controls on system functioning

In order to understand the form and function of the River Wharfe SSSI, floodplain and catchment system, it is necessary to identify controls on behaviour, highlighting patterns of channel change in response to multiple drivers. In order to achieve this, the following must be recognised:

- Catchment processes strongly influence system hydromorphology with process linkages occurring across large scales.
- Considerable modification has occurred to the system form and process both in the past and now. The system is responding to these modifications.
- The channel and floodplain must be treated as a single functional unit ensuring that channel and floodplain processes are restored together to create a sustainable dynamic naturalising system.
- Interactions occur between the hydromorphology (geomorphology, hydrology, hydraulics) and ecology to influence the present state and dynamics of the system.
- The system is both sensitive and dynamic and interventions and alterations to the form and process will invoke a reaction which must be both predictable and acceptable within the context of wider use of the river and catchment.

As such it is vital in this study to identify the process – behaviour linkages present in the catchment, identifying the controls on sediment movement and associated sedimentation and erosion along the watercourses (Figure 3-4).

Figure 3-4 Principal controls on the character and dynamics of the River Wharfe SSSI.



3.5 Sediment sources and sinks

3.5.1 Sediment sources

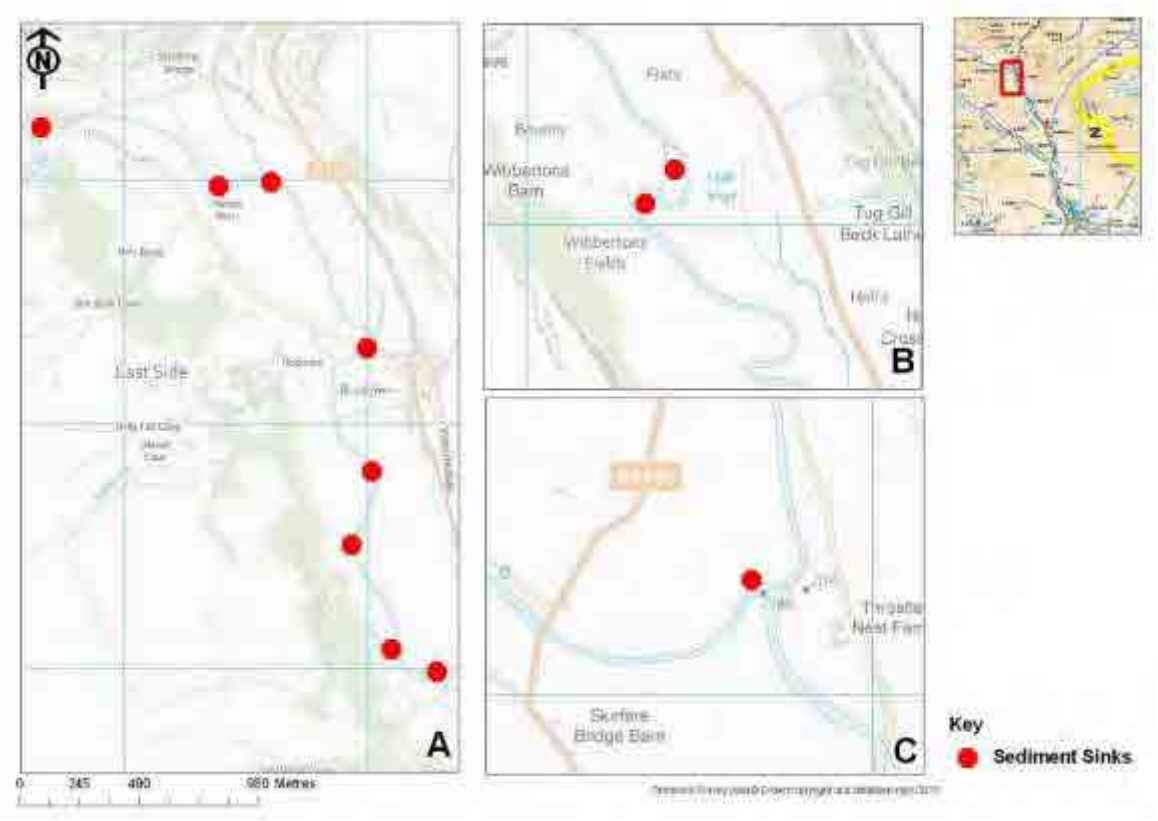
Generally the upper catchment of the Wharfe is stable. However, significant point sources of coarse sediment exist associated with the following conditions:

- Erosion of till deposits along upland gills
- Soil creep processes slowly moving valley side till towards the headwater delivery channels
- Erosion of valley side till with associated downslope transport
- Erosion of previously deposited fluvio-glacial deposits in upland valleys
- Erosion of previously deposited fluvial berms along upland gills
- Direct inputs from scree deposits adjacent to watercourses
- Downstream movement of stored coarse sediment in upland watercourses

3.5.2 Sediment sinks

Gravel accumulations are frequent along the upper River Wharfe (Figure 3-5) creating wandering reaches separated by sinuous single thread channels. These sinks are continually evolving and new sink areas are also developing. This dynamic must be accounted for in any river naturalisation plan.

Figure 3-5 Gravel accumulation zones (sediment sinks) along the upper River Wharfe SSSI.



3.6 Reach-scale characteristics

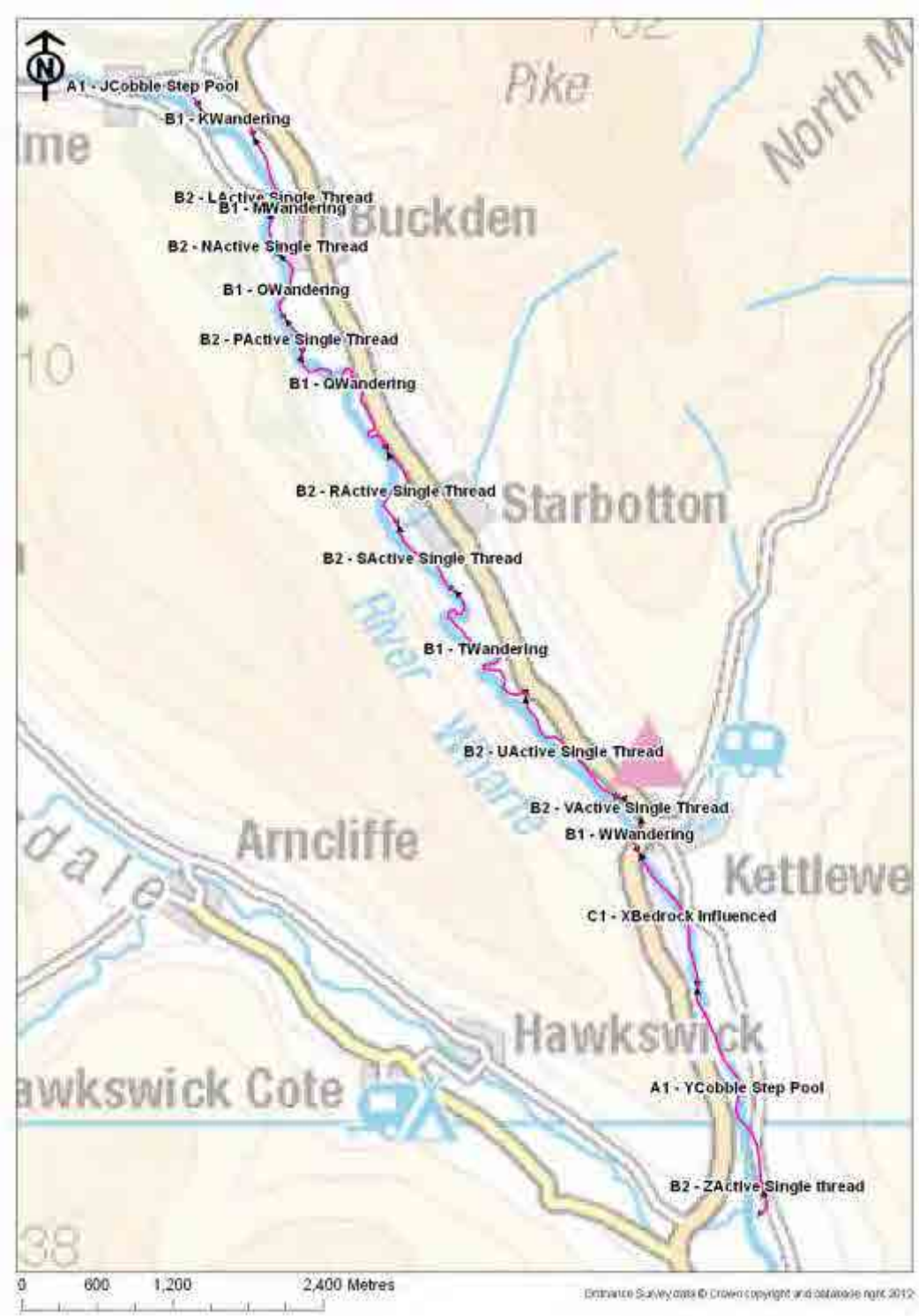
Four principal river types have been identified along the River Wharfe SSSI; cobble step-pool (reach code A), Incipient wandering (reach code B1), Active single thread (reach code B2) and bedrock influenced single thread (reach code C). The distribution of each channel type is strongly linked with channel gradient (Figure 3-7 and

Figure 3-8) with local slope changes influencing sediment transport processes and leading to altered channel morphology. Two other modified channel types have also been mapped, straightened (Reach code B3) and cobble plane bed (reach code B4).

3.7 Reach breakdown

Figure 3-6 defines the reach breaks identified during the combined hydromorphic and ecological survey of the SSSI. It is clear that fully alluvial reaches exhibit alternating active single thread and wandering channel types. Confined reaches are characterised by bedrock influenced or cobble bed step-pool systems.

Figure 3-6 River Wharfe SSSI channel reach type breakdown



The tables below and those contained within Appendix 10 only highlight reach-specific issues and not the generic opportunities and issues that are applicable throughout the SSSI. For example, the presence of North American Signal Crayfish is likely throughout the river therefore any in-channel working is likely to be constrained by the presence of this species and an appropriate biosecurity protocol. However, any works may provide opportunity to control this species within the river. Likewise, Otter is likely to be present throughout the surveyed reach as extensive evidence was found during the survey. Any significant capital works to the river or

surrounding habitats have the potential to impact on areas that potentially could be used by Otter as a holt, couch or resting place. Once restoration options have been developed, further surveys are likely to be required to assess any potential impacts, and mitigation requirements, on Otter.

For each reach hydraulic modelling was undertaken using JFLOW (see Appendix 2). A series of flows were run through the JFLOW model to determine at which flows out of bank flow occurred. Where a lower flow results in floodplain wetting, this indicates reasonable floodplain connectivity under present conditions (i.e. the 25m^3/s and 45m^3/s flows) and presents an opportunity for floodplain connectivity improvements as groundwork requirements would be reduced where there is already reasonable connectivity. For the 65m^3/s and 100m^3/s flows, these represent poor floodplain connectivity and therefore opportunities to improve this in these areas are unrealistic given the level of groundwork that would be required. In some cases, little out-of-bank flow would be expected due to the v-shaped valley in some locations.

Figure 3-7 Long section of the River Wharfe SSSI: upper reach

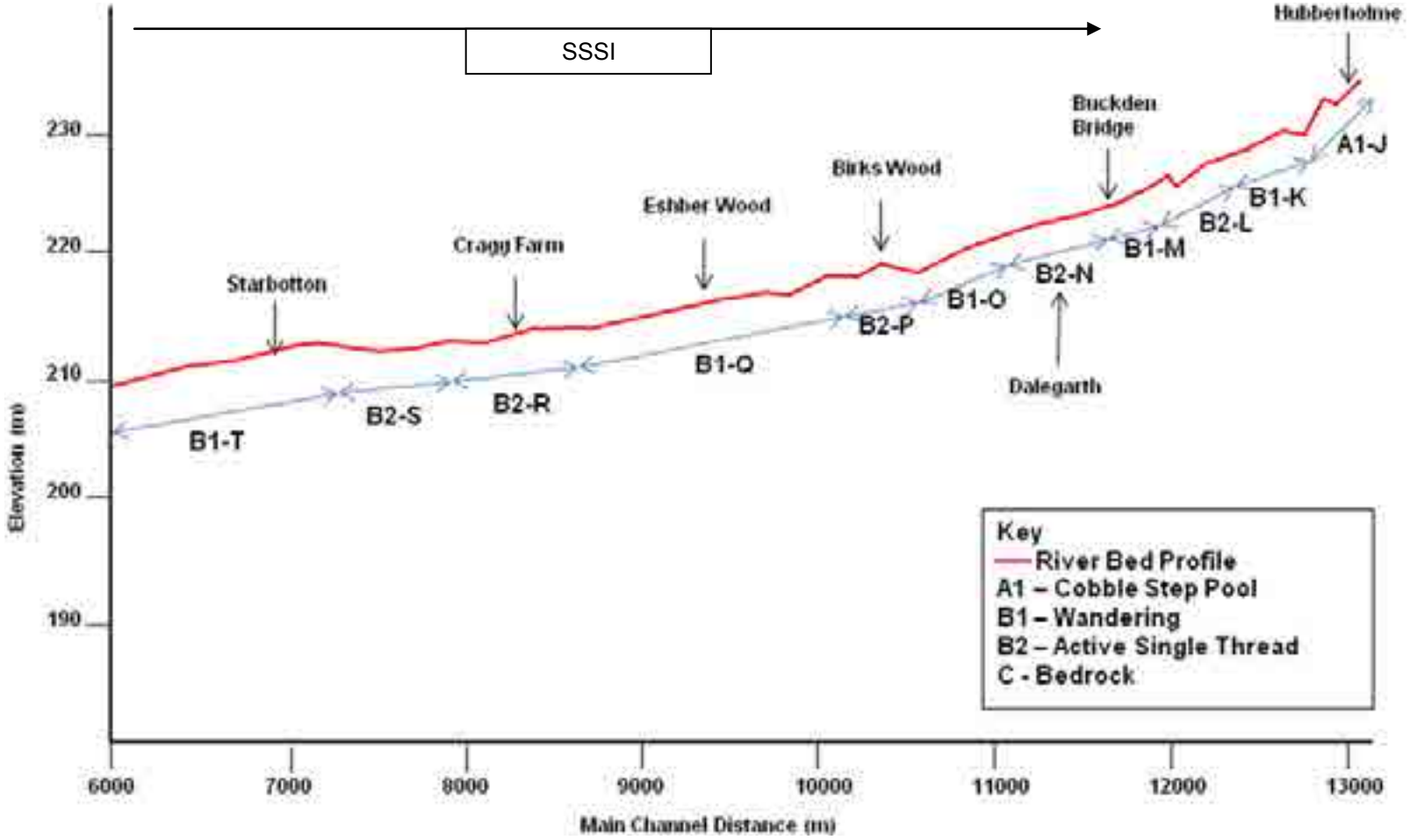
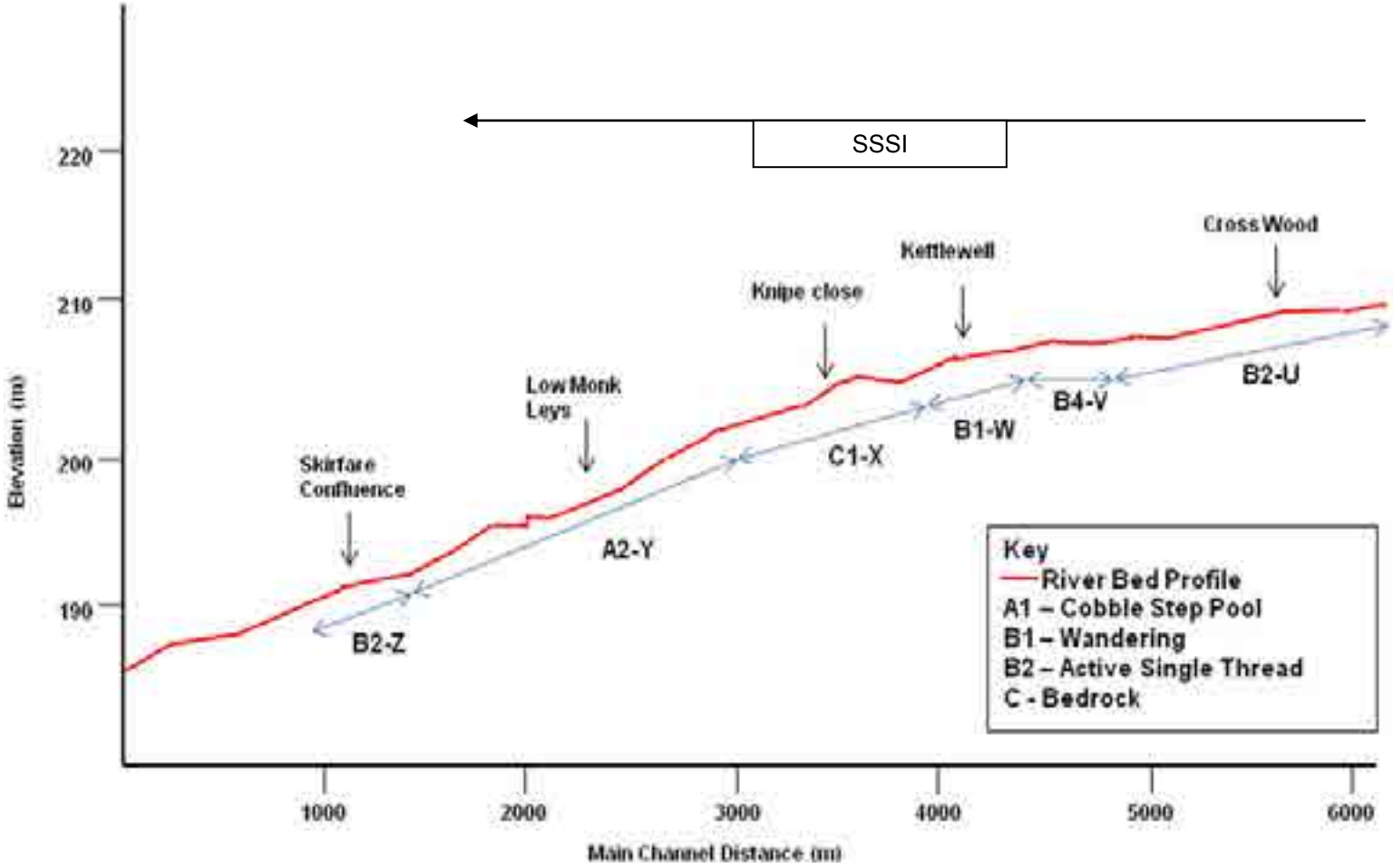


Figure 3-8 Long section of the River Wharfe SSSI: Lower reach.



3.7.1 Cobble step-pool (reach code A).

The channel is generally steep and is characterised by a coarse sediment bed of cobbles and boulders, often with a sparse covering of aquatic mosses (e.g. Alpine Water-moss, Fountain Feather-moss, Brook-side Feather-moss). The channel is quite confined and displays occasional, often wooded, stable islands, boulder and cobble steps and rapids and intervening pool areas (Figure 3-9). Lateral movement is restricted due to the size of the bed material and the frequent presence of bedrock. The stability of the channel location has resulted in the development of mature, linear Ash, Alder and Sycamore woodland on the bank tops. Channel scouring is also very limited due to the armoured nature of the bed, which also results in limited opportunities for aquatic macrophyte development, leading to a species-poor, bryophyte-dominated flora in these reaches.

Figure 3-9 Cobble step-pool river type on the River Wharfe SSSI.

3.7.2 Wandering (reach code B1).

Wandering reaches are characterised by a moderately steep gradient and by extensive gravelly deposits and active lateral movement. The channel is set in a wider valley but is often over-deep due to gravel removal and fluvial incision linked partly to the confinement of flood flows between adjacent flood banks. The river is characterised by large gravel bars (point, mid and lateral) with occasional plane bed reaches and deeper pools (Figure 3-10).

This morphological diversity gives rise to a number of habitats within the river corridor, including;

- Recently deposited gravel bars, or those subject to regular inundation or reworking, with sparse vegetation cover, usually including Creeping Bent *Agrostis stolonifera,* Colt's-foot *Tussilago farfara,* Butterbur *Petasites hybridus,* Ribwort Plantain *Ranunculus acris* and Field Horsetail *Equisetum arvense*, along with wetland species such as Marsh Marigold *Caltha palustris* and Water Mint *Mentha aquatica.*
- More established and stabilised gravel bars, with denser vegetation cover, where the sward is often grassy with Creeping Bent, Cock's-foot *Dactylis glomerata* and Yorkshire Fog *Holcus lanatus* abundant. Species such as Broad-leaved Dock *Rumex obtusifolius* also become more prevalent, along with small saplings of Crack Willow and other trees.
- An active channel with few or no aquatic macrophytes present. Alpine Water-moss and Fountain and Brook-side Feather-mosses may be present on the boulders within the channel.

- Stagnant backwaters, often behind gravel deposits, and the inside of bends where flows are more sluggish allow the establishment of a greater variety of aquatic and wetland species; Marsh Marigold, Water-milfoil species *Myriophyllum sp*. and Common Water-starwort *Callitriche stagnalis* recorded.
- Lateral movement is strong but localised and is intrinsically linked to bar deposition.

Figure 3-10 Wandering river type on the River Wharfe SSSI.

3.7.3 Active single thread (reach code B2).

This river type is less steep and is characterised by a gravelly bed. The channel is set in a wider valley but is often over-deep due to gravel removal and fluvial incision linked partly to the confinement of flood flows between adjacent flood banks. The river displays stable riffle-pool sequences with occasional plane bed reaches, point bars and lateral bars (Figure 3-11). Again, aquatic mosses (e.g. Alpine Water-moss and Fountain Feather-moss) are the most frequent component of the aquatic flora, but do not cover significant areas as the gravel dominated channel leaves few rocks on which the mosses can grow. In occasional slack areas along the channel margins small patches of wetland species, such as Water-cress *Rorippa nasturtium-aquaticum* develop.

Lateral movement is restricted due to the presence of bank protection and the reduced fluvial energy through these reaches, which in places has resulted in the development of mature, linear Ash and Sycamore woodland on the banks. Channel scouring is also localised and often linked to previous engineering works.

Figure 3-11 Active single thread-pool river type on the River Wharfe SSSI.

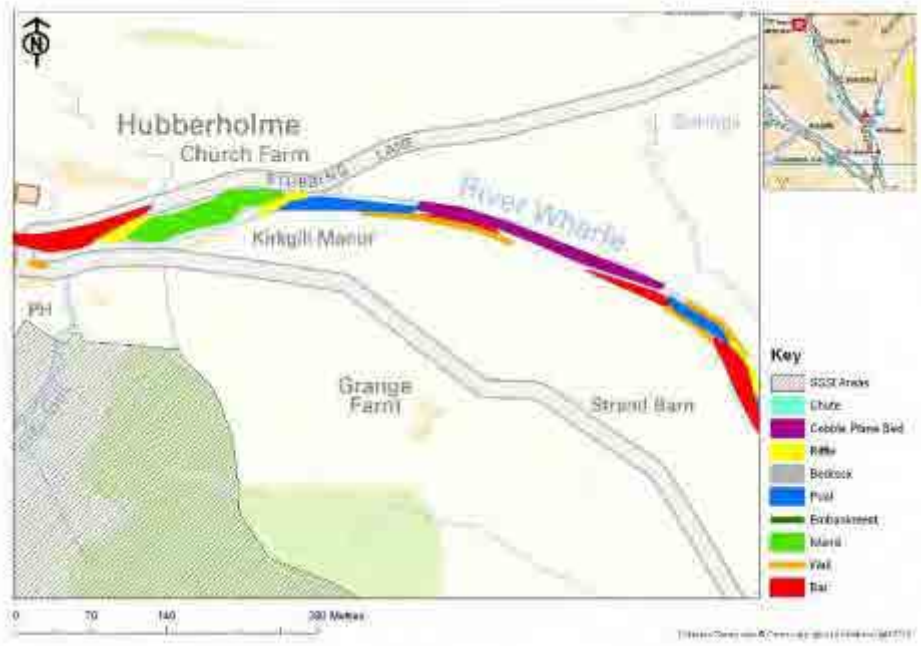
3.7.4 Bedrock influenced single thread (reach code C).

Bedrock reaches on the river are characterised by a very steep gradient and the channel is very efficient at transporting delivered sediment. As a result the bed displays very little in the way of sedimentary deposits and bedrock is exposed extensively across the bed and along the banks (Figure 3-11). As a result there are few, if any, aquatic macrophytes within the channel, although Fountain Feather-moss is abundant on the bedrock outcrops and large boulders within the channel. The channel is set in a generally confined, narrow valley, which for the most part is lined with mature Ash and Sycamore woodland. Lateral movement is extremely limited due to bedrock influence and woody vegetation. Similarly channel incision is not occurring.

Figure 3-12 Bedrock influenced river type on the River Wharfe SSSI.

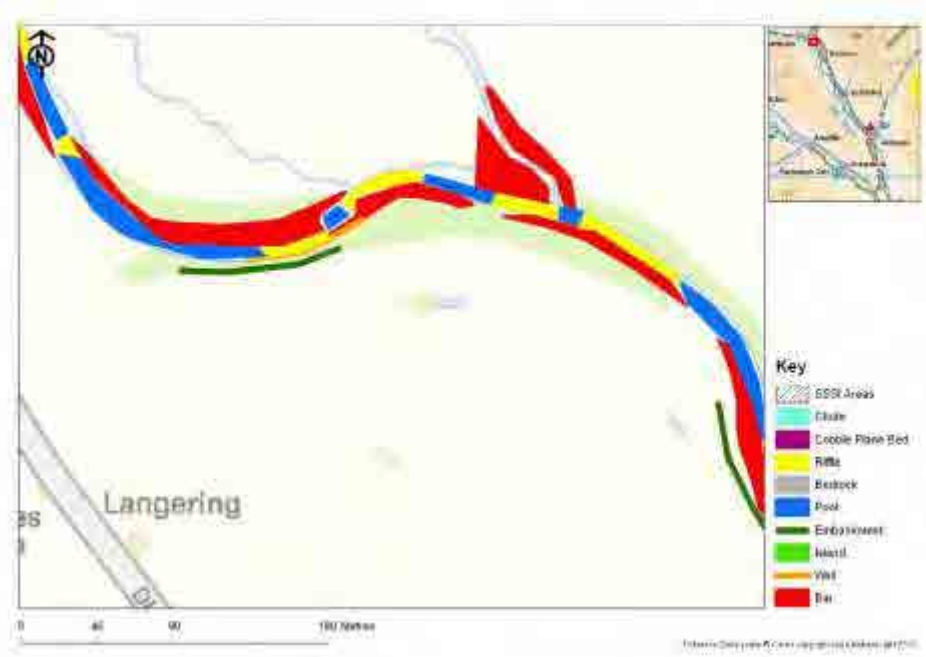
3.8 Reach descriptions

3.8.1 Reach A1 - J: Cobble step-pool (outside the SSSI)



Channel Condition		Floodplain Condition	
River Type (s)	Cobble bed with some level step pool sequences	Valley Type	Narrow floodplain
Responsiveness	High energy, transporting reach with limited gravel deposition, aquatic vegetation development and storage within the channel	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	Deposition within this section is limited. Where there are small deposits, these tend to be of a large cobble, even small boulder size.	Riparian Vegetation	Tree lined channel banks - Ash, Sycamore and willows
Morphology	Pool, riffle, islands, plane bed and bar development	Palaeo features	None
Incision	Yes – floodplain levels within this reach are generally 2m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	Limited poaching or grazing pressures due to riparian vegetation
Engineering	Walls lining the edge of the channel		
Bank activity	Limited bank activity due to stabilisation by trees and walls		
Aquatic vegetation	Limited with aquatic mosses on the boulders		

3.8.2 Reach B1 - K: Incipient Wandering (outside the SSSI)

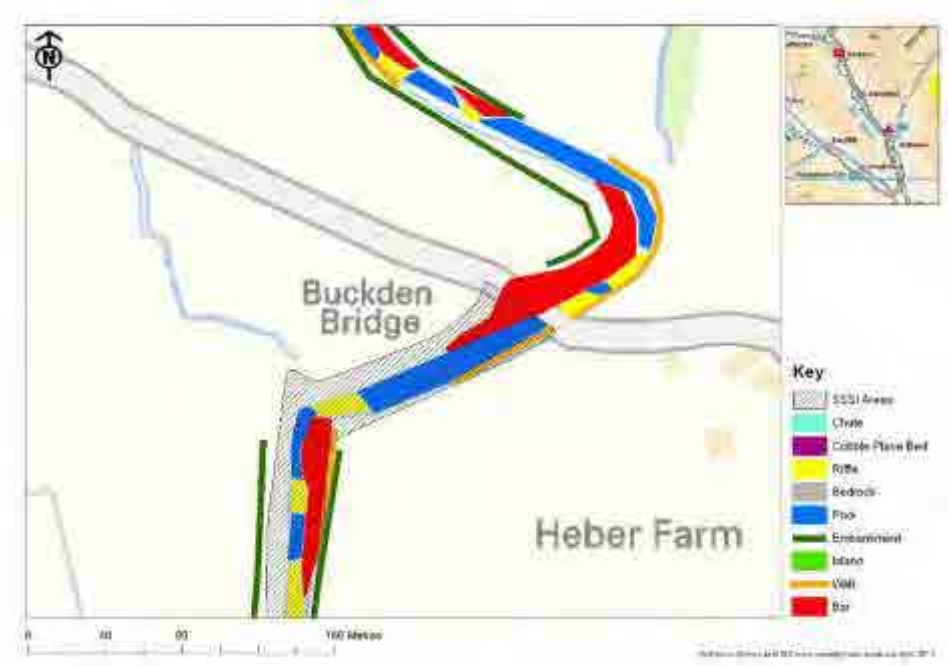


Channel Condition		Floodplain Condition	
River Type (s)	Wandering reach dominated by pools, riffles and deposition	Valley Type	Narrow floodplain
Responsiveness	High energy, transporting reach with limited gravel deposition, aquatic vegetation development and storage within the channel	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	This reach is characterised by pockets of localised erosion and deposition	Riparian Vegetation	Tree lined channel banks - Ash, Sycamore and willows
Morphology	Pool, riffle, islands, plane bed and bar development	Palaeo features	Upstream of Buckden woods. Reconnection possible
Incision	Limited– floodplain levels within this reach are generally 0.5 m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	Limited poaching or grazing pressures due to riparian vegetation
Engineering	Walls lining the edge of the channel. Former Buckden gravel trap		
Bank activity	Limited bank activity due to stabilisation by trees and walls		
Aquatic vegetation	Where gravel deposition has occurred habitat diversity within the channel is relatively high, with sparsely vegetated, actively reworked deposits to densely vegetated stable bars.		

3.8.3 Reach B2 – L: Active Single Thread (outside the SSSI)

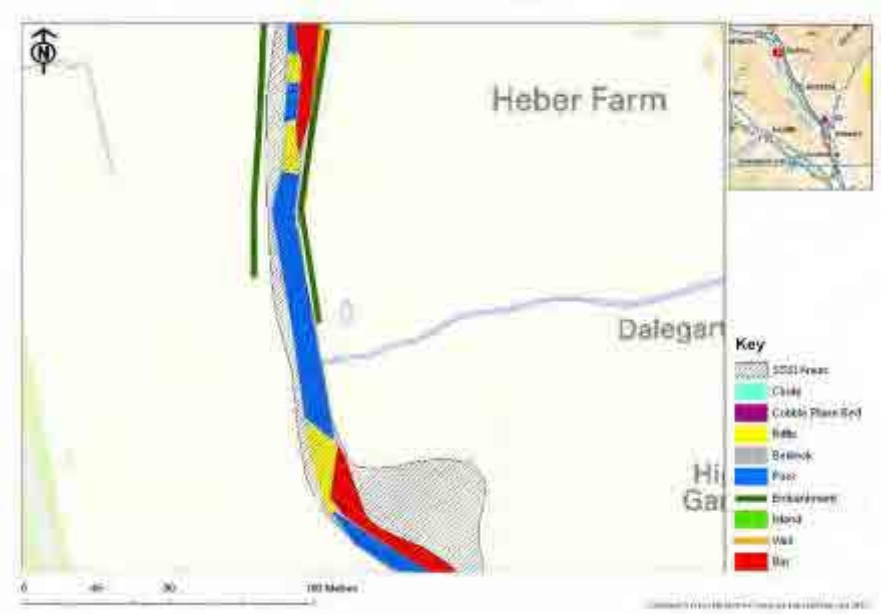
Channel Condition		Floodplain Condition	
River Type (s)	Active single thread	Valley Type	Narrow floodplain
Responsiveness	This reach is more transportational than reach B1 – K upstream, with fewer in-channel deposits of gravels and cobbles	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	Where deposits do exist these tend to be as thin lateral bars at the bank toe, often composed of larger cobbles, several with a covering of aquatic mosses. Longer riffles are evident through this section with some plane bed sections	Riparian Vegetation	Tree lined channel banks - Ash, Sycamore, Crack Willow and Alder trees
Morphology	Pool, riffle, chutes and bar development	Palaeo features	Left bank upstream of Buckden. Reconnection possible.
Incision	Yes – floodplain levels within this reach are generally 1m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	Limited poaching or grazing pressures due to riparian vegetation
Engineering	Walls lining the edge of the channel		
Bank activity	Limited bank activity due to stabilisation by trees and walls		
Aquatic vegetation	Limited with aquatic mosses on the boulders		

3.8.4 Reach B1 – M: Incipient Wandering



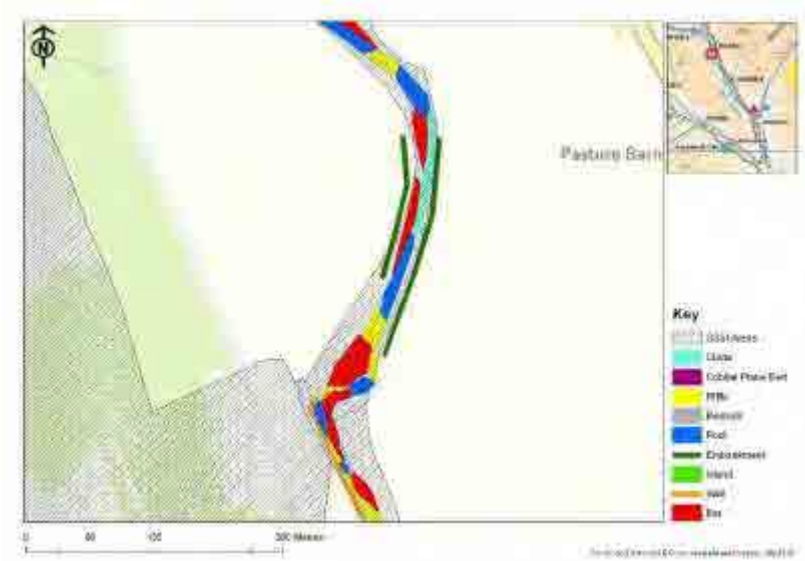
Channel Condition		Floodplain Condition	
River Type (s)	Wandering reach	Valley Type	Narrow floodplain
Responsiveness	This reach contains more gravels than the previous upstream reach. Gravel is deposited at the tight meander bend at Buckden Bridge.	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	This reach is supplied by the upstream B2 – L transportational reach and the hydraulic impacts of the meander bend have led to the development of the point bar at Buckden Bridge, composed of mainly a mixed gravel fraction with some smaller cobbles.	Riparian Vegetation	Tree lined channel banks - Ash, Sycamore, Crack Willow and Alder trees. The fields on the right bank floodplain generally consist of improved, poor semi-improved and neutral semi-improved grassland fields
Morphology	Pool, riffle and bar development	Palaeo features	None
Incision	Yes – floodplain levels within this reach are generally 1m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	Limited poaching or grazing pressures due to riparian vegetation
Engineering	The revetment protecting the outer bank of the meander downstream of Buckden Bridge is failing resulting in undercutting. Embankments exist as part of a flood alleviation scheme. Historically gravel has been removed from the area around Buckden Bridge.		
Bank activity	Limited bank activity due to stabilisation by trees and walls		
Aquatic vegetation	Limited with aquatic mosses on the boulders		

3.8.5 Reach B2 – N: Active Single Thread



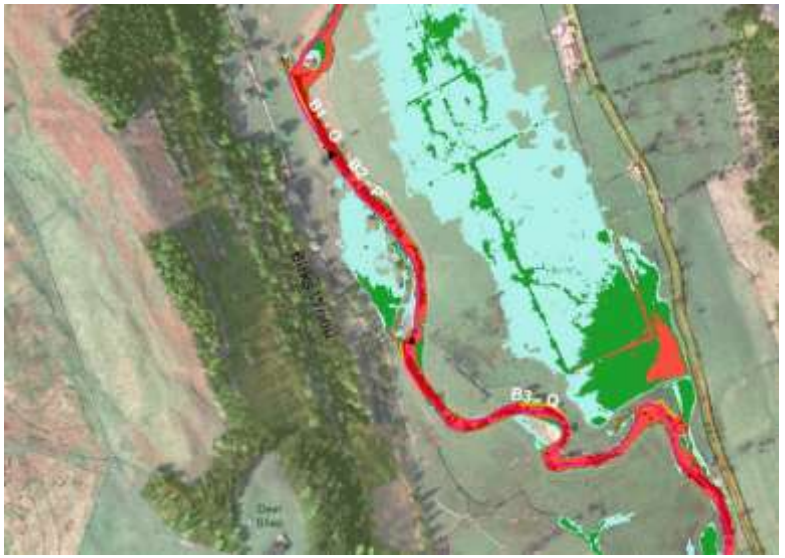
Channel Condition		Floodplain Condition	
River Type (s)	Active single thread	Valley Type	Narrow floodplain
Responsiveness	This reach is more transportational with fewer in-channel deposits of gravels and cobbles	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	This reach is supplied by the upstream B2 – L transportational reach and the hydraulic impacts of the meander bend have led to the development of the point bar at Buckden Bridge, composed of mainly a mixed gravel fraction with some smaller cobbles.	Riparian Vegetation	Tree lined channel banks - Ash, Sycamore, Crack Willow and Alder trees.
Morphology	Pool, riffle and bar development	Palaeo features	None
Incision	Yes – floodplain levels within this reach are generally 1.5m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	Limited poaching or grazing pressures due to riparian vegetation
Engineering	Banks are generally protected by revetment throughout the reach on both sides of the channel. Flood embankments lining both banks, built as part of the Buckden FAS are likely to have been increased in height through dredging deposits, limiting floodplain connectivity		
Bank activity	Limited bank activity due to stabilisation by trees and walls. Where trees don't exist bank erosion was noted		
Aquatic vegetation	Where Buckden Beck joins the Wharfe a small stand of Japanese Knotweed was recorded		

3.8.6 Reach B1 – O: Incipient Wandering



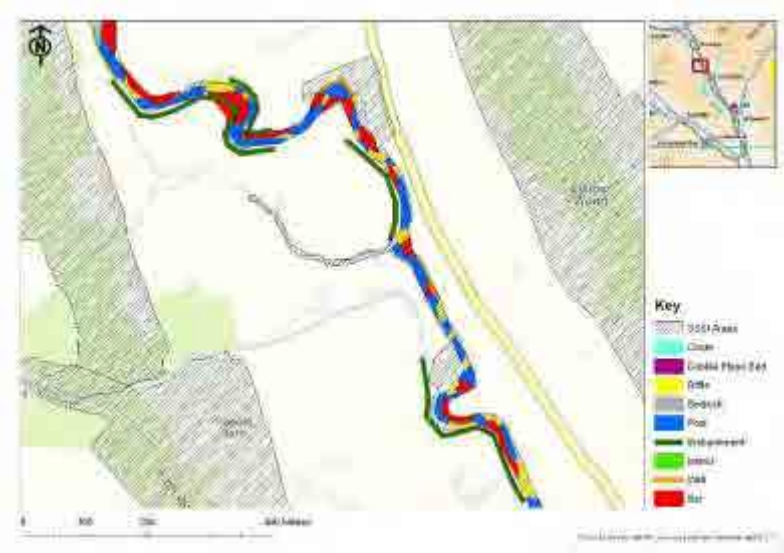
Channel Condition		Floodplain Condition	
River Type (s)	Wandering	Valley Type	Narrow floodplain
Responsiveness	This reach is depositional with significant in-channel gravel / cobble features such as lateral bars, mid-channel bars and point bars	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	This reach provides a good example of progressive upstream sedimentation where the development of large in-channel deposits impounds a significant length of watercourse upstream, creating conditions locally that promote the development of another in-channel deposit. The most significant deposit within this reach has encouraged channel widening locally (indicated by old bank protection lines that have been flanked), and has also created a chute channel on the right side of the deposit.	Riparian Vegetation	Limited tree cover along the banks. The floodplain is dominated by improved grass land coverage.
Morphology	Pool, riffle, chute and bar development	Palaeo features	Right bank. Re-connection from this reach would be limited.
Incision	Yes – floodplain levels within this reach are generally 1.5m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	Some poaching and grazing pressures were noted due to the lack riparian vegetation
Engineering	Banks are generally protected by revetment throughout the reach on both sides of the channel. Flood embankments lining both banks, built as part of the Buckden FAS are likely to have been increased in height through dredging deposits, limiting floodplain connectivity		
Bank activity	Areas of bank erosion		
Aquatic vegetation	Vegetated mid channel bars and pools which provide refuges for juvenile fish, several shoals of which were observed in this area during the survey work		

3.8.7 Reach B2 – P Active Single thread



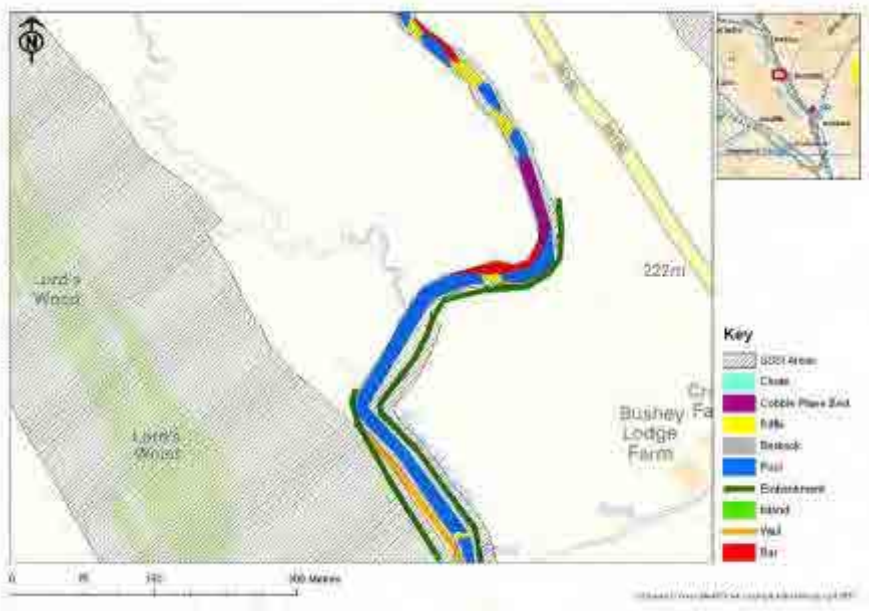
Channel Condition		Floodplain Condition	
River Type (s)	Active single thread	Valley Type	Narrow floodplain
Responsiveness	This reach is more transportational with fewer in-channel deposits of gravels and cobbles	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	There is one lateral bar on the right bank that is stabilised and vegetated and does not appear to be dynamic under current conditions. Riffle-pool sequencing is moderately well developed through this reach	Riparian Vegetation	Limited tree cover along the banks. The floodplain is dominated by improved grass land coverage.
Morphology	Pool, riffle, chute and bar development	Palaeo features	Right bank. Re-connection from this reach would be limited.
Incision	Yes – floodplain levels within this reach are generally 0.5m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	Some poaching and grazing pressures were noted due to the lack riparian vegetation
Engineering	Bank protection is less common through this section. However, there are several localised points where protection does exist.		
Bank activity	Areas of bank erosion		
Aquatic vegetation	Vegetated mid channel bars and pools which provide refuges for juvenile fish, several shoals of which were observed in this area during the survey work		

3.8.8 Reach B1 – Q Wandering



Channel Condition		Floodplain Condition	
River Type (s)	Wandering	Valley Type	Narrow floodplain
Responsiveness	This reach is a wandering depositional reach with frequent point bars and lateral bars	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	In many instances the channel is well connected to the floodplain and is actively wandering and eroding. Bars consist of gravels and cobbles	Riparian Vegetation	Currently this floodplain has a diverse range of habitats, including a cut-off meander, Lesser Pond-sedge beds, Grey Willow-dominated areas of wet woodland, areas of marshy grassland dominated by Meadowsweet and a significant extent of Soft Rush-dominated rushy pasture, all interspersed with areas of poor semi-improved grazed pasture
Morphology	Pool, riffle, chute and bar development	Palaeo features	Several. Historically, the channel has moved across the floodplain through this section
Incision	Yes – floodplain levels within this reach are generally 0.5m higher than the normal water level in the Wharfe	Poaching and Grazing Pressures	The floodplain in this area is sheep and cattle grazed and in places poaching of the banks is significant
Engineering	Bank protection is less common through this section. However, there are several localised points where protection does exist.		
Bank activity	Areas of active bank erosion		
Aquatic vegetation	Limited in channel vegetation. Areas of marshy grassland and swamp		

3.8.9 Reach B2 – R Active Single Thread

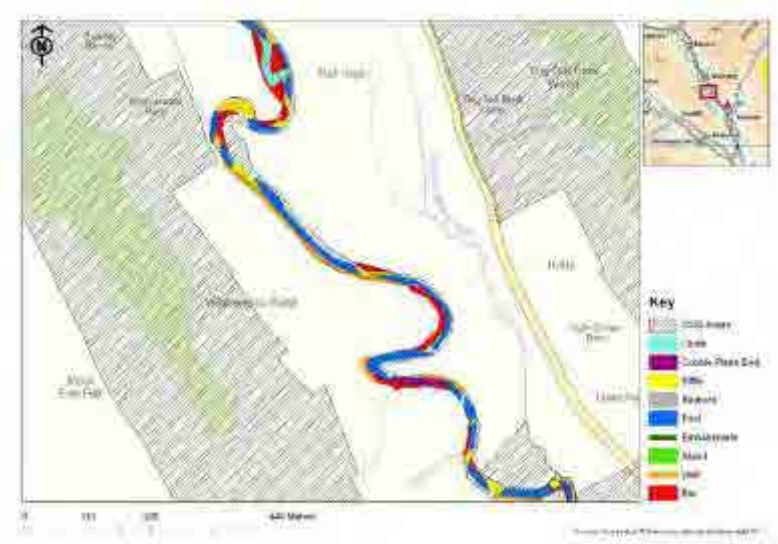


Channel Condition		Floodplain Condition	
River Type (s)	Active single thread	Valley Type	Narrow floodplain
Responsiveness	This reach becomes more transportational with fewer in-channel deposits of gravels and cobbles	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	In many instances the channel is well connected to the floodplain and is actively wandering and eroding. Bars consist of gravels and cobbles	Riparian Vegetation	Wet woodland and rushy pasture.
Morphology	Pool, riffle, chute and bar development	Palaeo features	Right bank. Better connection could be achieved.
Incision	Yes – This reach appears to be incised meaning floodplain connectivity is limited. The floodplain is >2m above the normal water level in the Wharfe	Poaching and Grazing Pressures	Some poaching and grazing pressures were noted due to the lack riparian vegetation
Engineering	Embankments line the edges of the channel and bank protection is common in several areas		
Bank activity	Limited bank activity due to stabilisation by trees and walls		
Aquatic vegetation	in-channel vegetation is limited due to limited in channel deposition		

3.8.10 Reach B2 – S Active single thread - Plane Bed

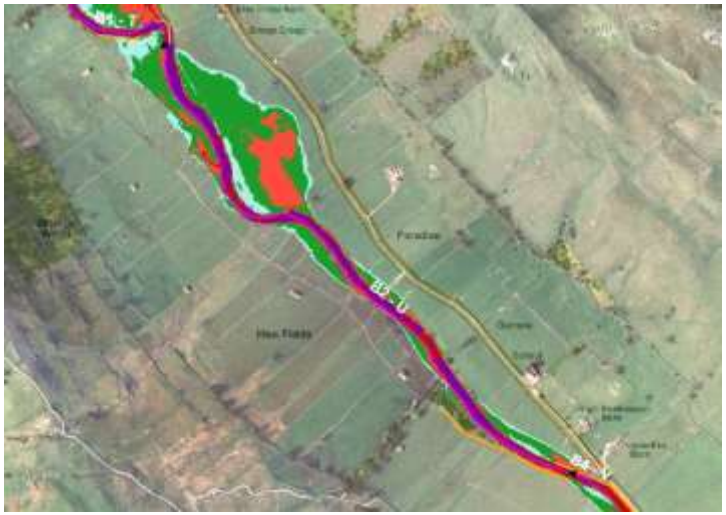
Channel Condition		Floodplain Condition	
River Type (s)	Active single thread - Plane bed	Valley Type	Narrow floodplain
Responsiveness	This reach is generally a transportational plane bed cobble and gravel, despite a significant source of coarse sediment from Cam Gill Beck and Fosse Gill	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	Sediment input from tributaries. The reach is straight and has few in-channel depositional features, barring one part vegetated, small point bar	Riparian Vegetation	Marshy pasture and improved grassland.
Morphology	Pool, riffle and bar development	Palaeo features	Left and right banks. Connectivity could be improved
Incision	Yes – This reach appears to be incised meaning floodplain connectivity is limited. The floodplain is 1-1.5m above the normal water level in the Wharfe	Poaching and Grazing Pressures	Some poaching and grazing pressures were noted due to the lack riparian vegetation
Engineering	Bank protection is common in several areas.		
Bank activity	Limited bank activity due to stabilisation by trees and walls		
Aquatic vegetation	In-channel vegetation is limited due to limited in channel deposition. Some small part vegetated bars were observed.		

3.8.11 Reach B1 – T Incipient Wandering



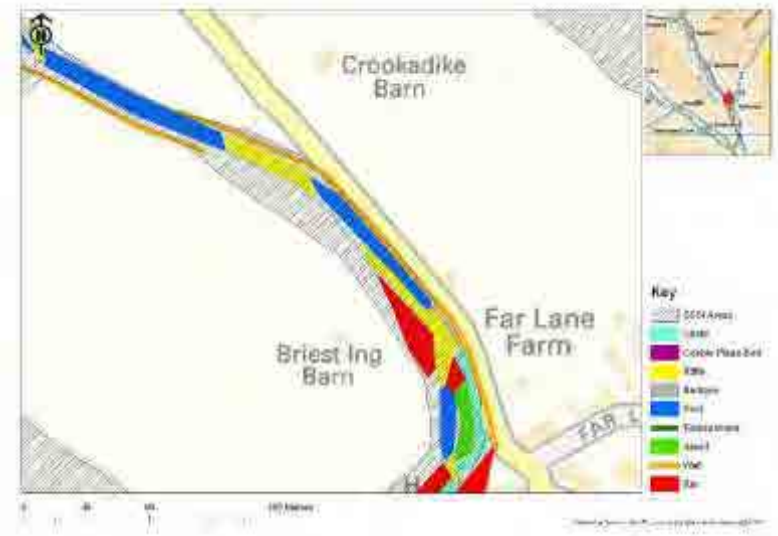
Channel Condition		Floodplain Condition	
River Type (s)	Wandering	Valley Type	Narrow floodplain
Responsiveness	This reach is depositional with significant in-channel gravel / cobble features such as lateral bars, mid-channel bars and point bars	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	The significant depositional features have created associated outer bank erosion with some local channel widening, again providing an important local sediment source to the system locally	Riparian Vegetation	Marshy pasture and improved grassland.
Morphology	Pool, riffle and bar development	Palaeo features	Floodplain palaeo channels have developed into chute channels through the large gravel bar deposit adjacent to Hall Ings, and these areas have considerable habitat and botanical diversity
Incision	Limited –The floodplain is <1m above the normal water level in the Wharfe in most instances	Poaching and Grazing Pressures	Some poaching and grazing pressures were noted due to the lack riparian vegetation
Engineering	Bank revetment is common along the reach.		
Bank activity	Bank erosion was observed in this reach		
Aquatic vegetation	Bars vary in vegetation cover and stability, with some developing grassland with species more typical of acidic conditions (see Target Note T in Appendix 4) and others with sparser vegetation cover and subject to more regular disturbance. Otter activity was extensive in this reach, particularly amongst the many deposited bars, along with evidence of non-native North American Signal Crayfish, evident from Otter feeding remains. The rare Northern Spike-rush was also recorded within this reach.		

3.8.12 Reach B2 – U Active Single Thread



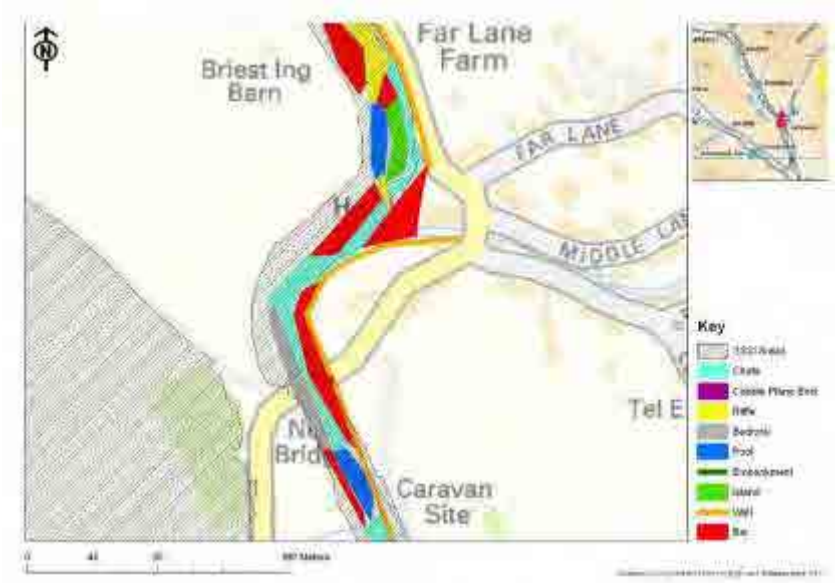
Channel Condition		Floodplain Condition	
River Type (s)	Active single thread	Valley Type	Narrow floodplain
Responsiveness	This section becomes transportational with limited in-channel depositional features, restricted to small bar features, consequently in-channel vegetation is also limited	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	Cobbles generally line the bed indicating gravels are readily transported downstream	Riparian Vegetation	There are flushed areas of Meadowsweet-dominated grassland. Also at the downstream end of Hush Gutter there is an area of particularly species-rich calcareous grassland, with a range of alpine and metal-tolerant species.
Morphology	Pool, riffle and bar development	Palaeo features	Floodplain palaeo channels have developed into chute channels through the large gravel bar deposit adjacent to Hall Ings, and these areas have considerable habitat and botanical diversity
Incision	Limited –The floodplain is <1m above the normal water level in the wharfe in most instances	Poaching and Grazing Pressures	Some poaching and grazing pressures were noted due to the lack riparian vegetation
Engineering	Limited bank revetment is present along the reach.		
Bank activity	Bank erosion was observed in this reach		
Aquatic vegetation	Limited in channel vegetation		

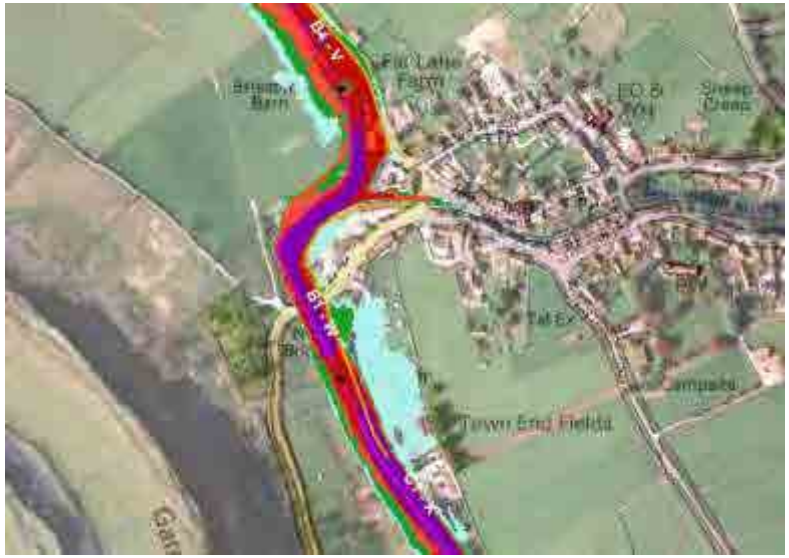
3.8.13 Reach B2 – V Active single thread - Plane bed



Channel Condition		Floodplain Condition	
River Type (s)	Active Single thread - Plane bed	Valley Type	Narrow floodplain
Responsiveness	This small, straight reach is transportational, with a cobbled, plane bed and no significant in-channel depositional features or aquatic macrophytes present, although aquatic mosses were present in this section.	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	Cobbles generally line the bed indicating gravels are readily transported downstream	Riparian Vegetation	A number of small stands, of the non-native, invasive Himalayan Balsam was present alongside the road
Morphology	Pool, riffle and bar development	Palaeo features	An old, now vegetated bar exists which would have been active under historic conditions
Incision	Floodplain connectivity is generally restricted through this reach as a result of the confined valley and high floodplain levels close to both banks	Poaching and Grazing Pressures	Some poaching and grazing pressures were noted due to the lack riparian vegetation
Engineering	Limited bank revetment is present along the reach.		
Bank activity	Bank erosion was observed in this reach		
Aquatic vegetation	Aquatic mosses were present		

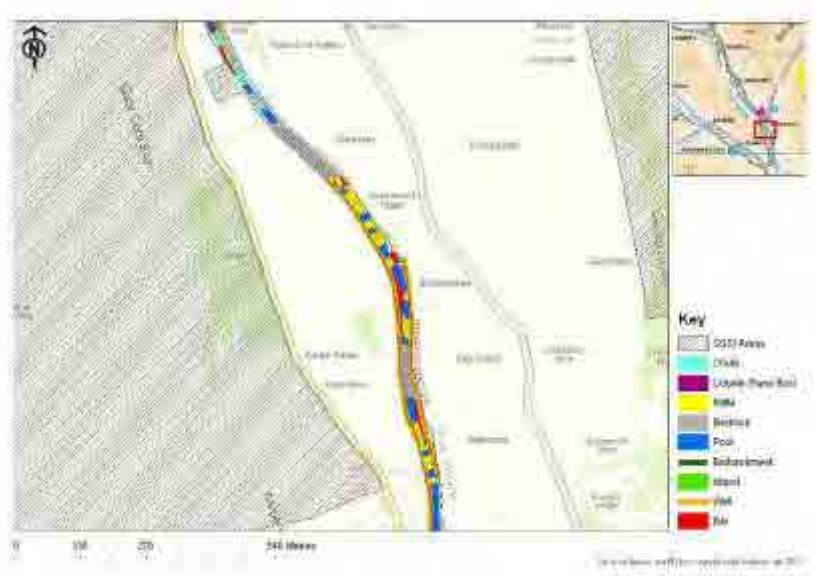
3.8.14 Reach B1 – W Incipient Wandering





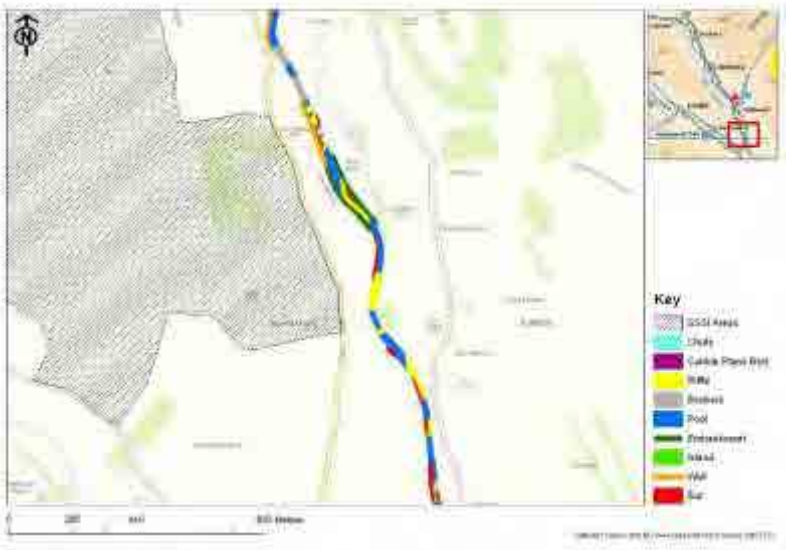
Channel Condition		Floodplain Condition	
River Type (s)	Wandering	Valley Type	Narrow floodplain
Responsiveness	The upstream transportational reach B2 – U and B4 – W supply this depositional reach.	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	There are significant gravel deposits at the confluence with Kettlewell Beck, as well as upstream where an island has developed creating bifurcated flow. This island is obviously relatively stable and densely vegetated with willow dominated scrub	Riparian Vegetation	Pasture and urban
Morphology	The reach is dominated by mid-channel bars (island), lateral bars and point bars, which are generally un- or sparsely vegetated. These are composed of a mixed gravel fraction with some cobbles	Palaeo features	None
Incision	Floodplain connectivity is generally restricted through this reach as a result of the confined valley and high floodplain levels close to both banks	Poaching and Grazing Pressures	Limited poaching and grazing pressures were noted
Engineering	Limited bank revetment is present along the reach.		
Bank activity	Bank erosion was observed in this reach		
Aquatic vegetation	Vegetated bars		

3.8.15 Reach C1 – X Bedrock Influenced



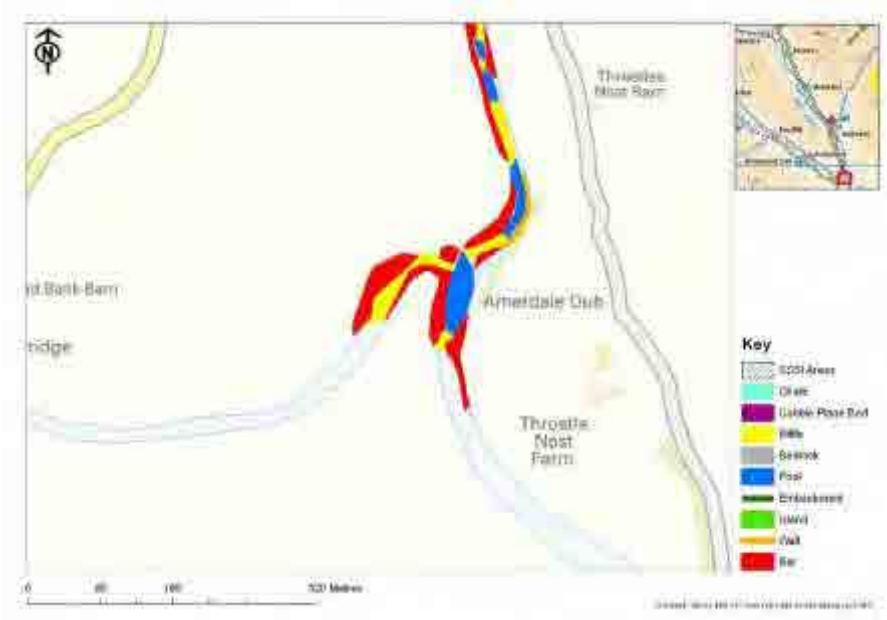
Channel Condition		Floodplain Condition	
River Type (s)	Bedrock	Valley Type	Narrow floodplain
Responsiveness	The reach is transportational with only small, sporadic deposits of larger cobbles, which exist mainly where there is local improved connectivity to the floodplain	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	Higher energy in-channel hydromorphic features are common including chutes and riffles	Riparian Vegetation	Semi-improved neutral grassland
Morphology	The reach is generally bedrock dominated, with large cobbles forming the majority of the bed, and some small boulders	Palaeo features	None
Incision	Floodplain connectivity is generally restricted through this reach as a result of the confined valley and high floodplain levels close to both banks	Poaching and Grazing Pressures	Limited poaching and grazing pressures were noted
Engineering	Revetments tend to line both banks, although the presence of bedrock is likely to limit any significant lateral migration.		
Bank activity	Little bank erosion was observed in this reach		
Aquatic vegetation	Some small vegetated bars and of Fountain Feather-moss covering boulders was observed		

3.8.16 Reach A2 – Y Cobble Step-Pool (outside the SSSI)



Channel Condition		Floodplain Condition	
River Type (s)	Cobble step pool	Valley Type	Narrow floodplain
Responsiveness	this reach is generally transportational with very few in-channel depositional features and a generally cobble lined bed	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	Riffle – pool sequencing are the dominant units through this reach and where small bars do exist, these have often become stabilised with mature vegetation, generally dominated by Reed Canary-grass	Riparian Vegetation	Semi-improved neutral grassland
Morphology	The reach is generally bedrock dominated, with large cobbles forming the majority of the bed, and some small boulders	Palaeo features	None
Incision	Floodplain connectivity is generally restricted through this reach as a result of the confined valley and high floodplain levels close to both banks	Poaching and Grazing Pressures	Limited poaching and grazing pressures were noted
Engineering	Revetments tend to line both banks, although the presence of bedrock is likely to limit any significant lateral migration.		
Bank activity	Little bank erosion was observed in this reach		
Aquatic vegetation	Aquatic vegetation was very limited, with little observed and all points surveyed by grapnel in this reach (points 40 to 45) did not return any species		

3.8.17 Reach B2 – Z Active Single Thread (outside the SSSI)



Channel Condition		Floodplain Condition	
River Type (s)	Active single thread	Valley Type	Narrow floodplain
Responsiveness	Whilst generally transportational, there are some in-channel depositional features, particularly close to the confluence with the Skirfare, composed of un-vegetated cobbles	Drainage	Several small tributaries impacted by upper catchment gripping
Sediment delivery, type and mobility	There is a riffle – pool sequence through this short reach, with a gravel deposit on the right bank. A significant amount of sediment enters the Wharfe from the Skirfare.	Riparian Vegetation	Adjacent meadows are species-rich and dominated by Meadowsweet and Lesser Pond-sedge
Morphology	A large pool has formed at the confluence with the Skirfare, but downstream of the confluence, depositional features are more common as the Skirfare is a significant gravel source to downstream reaches of the Wharfe	Palaeo features	None
Incision	Floodplain connectivity is generally restricted through this reach as a result of the confined valley and high floodplain levels close to both banks	Poaching and Grazing Pressures	Limited poaching and grazing pressures were noted
Engineering	Small scale bank protection		
Bank activity	There is a length of bank protection on the left bank		
Aquatic vegetation	Limited in channel vegetation		

4 System Pressures

4.1 Key Pressures identified during the reach scale assessment

4.1.1 Fine sediment and other pollutant supply from diffuse sources

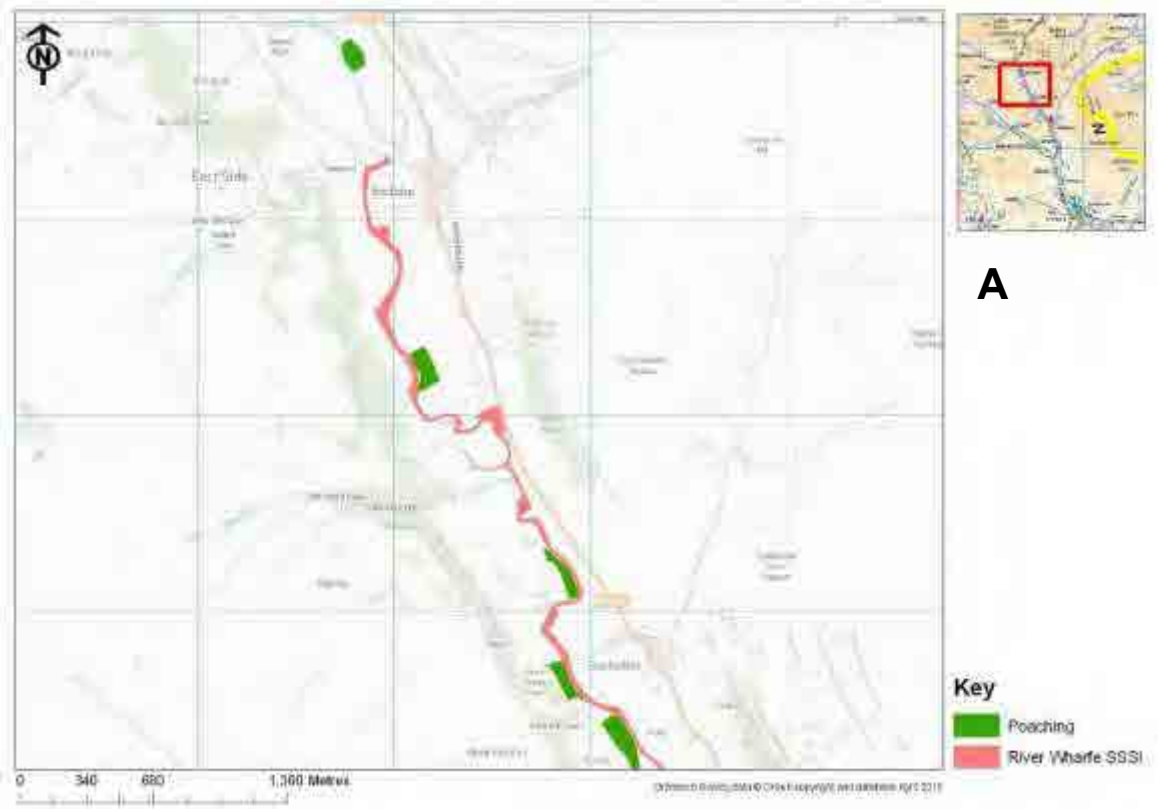
Fine sediment inputs to the River Wharfe appear to be within acceptable limits appropriate to the functioning of this system with little evidence of fine sediment choking of river gravels.

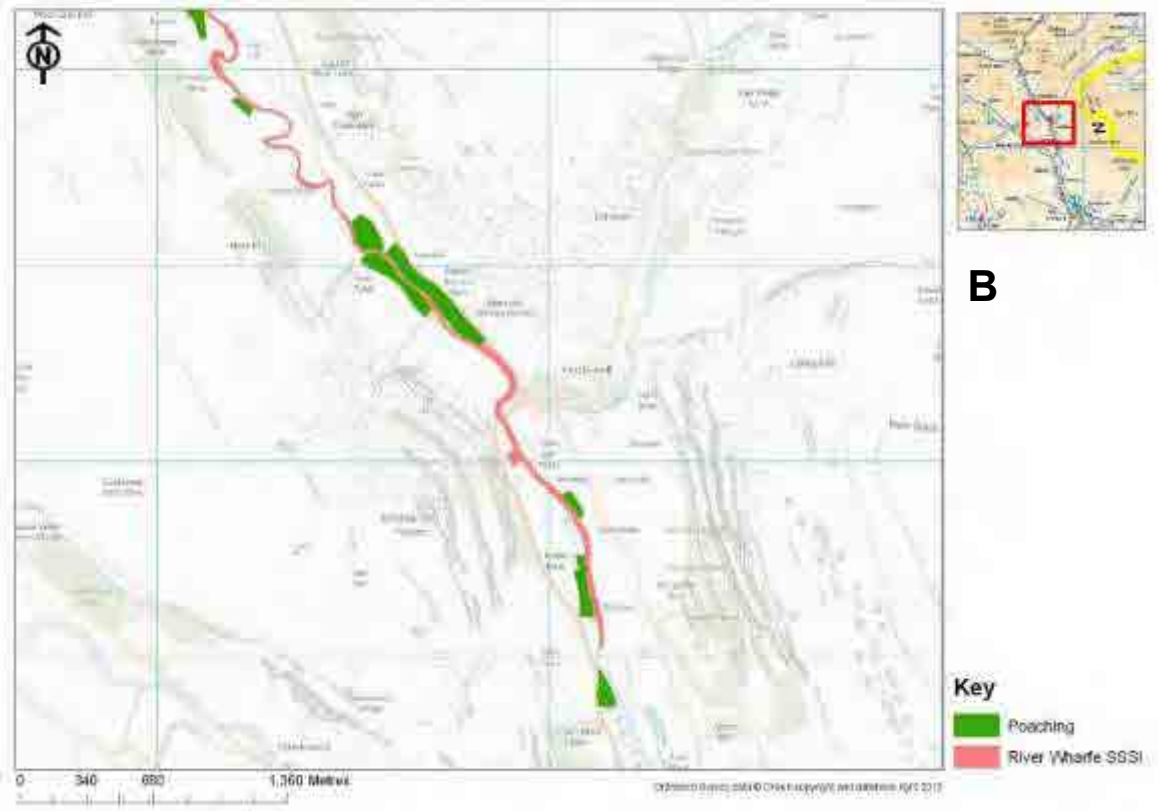
4.1.2 Fine sediment and other pollutant supply from point sources

There is evidence of extensive bank instability along the River Wharfe SSSI and this is most likely attributable to the effects of bed lowering through repeat historic dredging and the construction of adjacent flood banks encouraging in-channel bed erosion. Livestock have utilised the collapsed banks to gain access to the river in a number of locations (Figure 4-2) leading to localised gravel bed degradation. It should be noted that apparent poaching severity is strongly dependent on recent rainfall and all observations need to be treated as a snapshot of the problem only.

Figure 4-1 Example fine sediment source

Figure 4-2 Location of significant livestock poaching (green areas) along the River Wharfe SSSI maps A and B.





4.1.3 Flow regime alteration

The river exhibits a flashy flow regime (EA, 2000) and there is evidence that this has been intensified by moorland gripping in the upper catchment. Long term moorland restoration is underway. The entire SSSI is impacted.

Landuse in the upper catchment is dominated by forestry, open moorland grazing and pasture. Between 1960s and 1980s around 17km^2 of moor was been gripped to improve drainage, much of this across Oughtershaw Moss but with significant areas elsewhere in the upper catchment. Analysis of time to peak for the Wharfe has shown that flows are reaching their peak more rapidly since gripping. Peak flow magnitude increase is less apparent as can be seen from the annual maximum flow record for the Flint Mill gauging station and recent research (Lane and Milledge, 2012) in the catchment suggests that the drying out of the peat in gripped areas is creating increased storage for precipitation and may reduce flood magnitudes and time to peak (see section 3.2.2).

4.1.4 Channel realignment

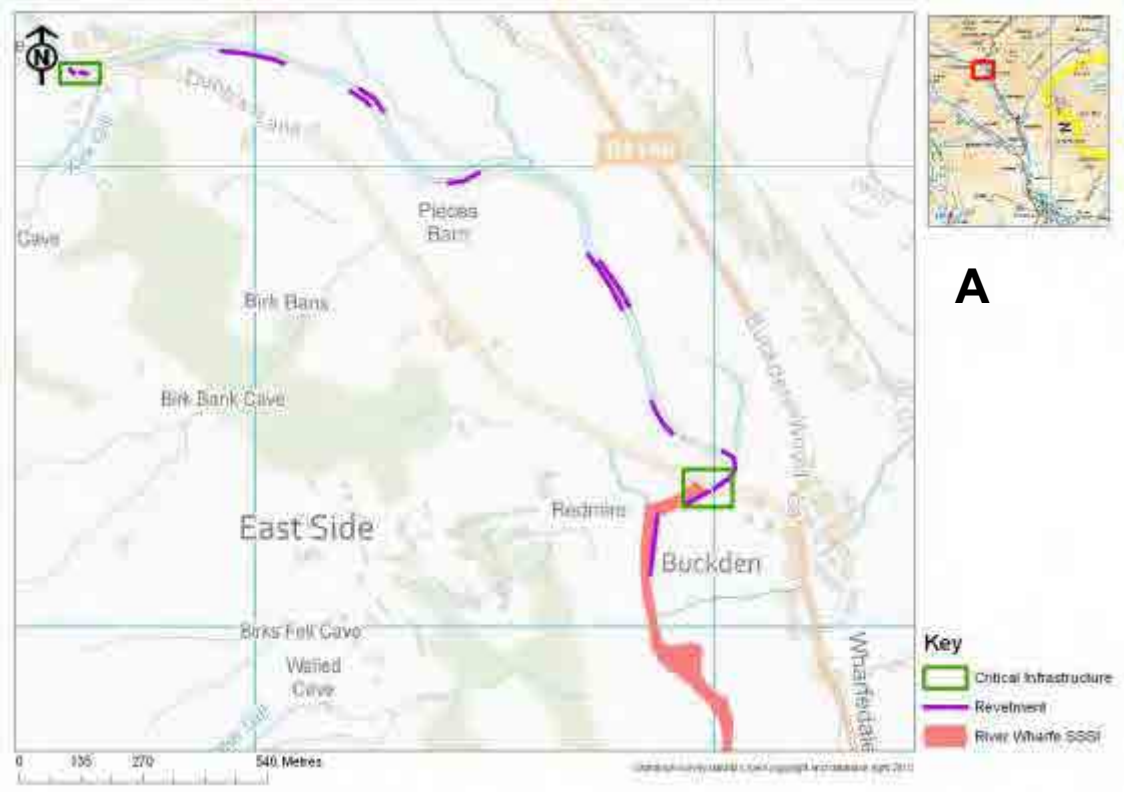
Documented evidence of historic channel straightening is rare. Analysis of aerial photographs of the river and floodplain suggest that realignment has occurred at several locations (Figure 4-3) leaving floodplain palaeo-features isolated in the landscape. Other areas may also have been straightened and have responded by cutting down into the bed rather than by eroding laterally due to the presence of revetment.

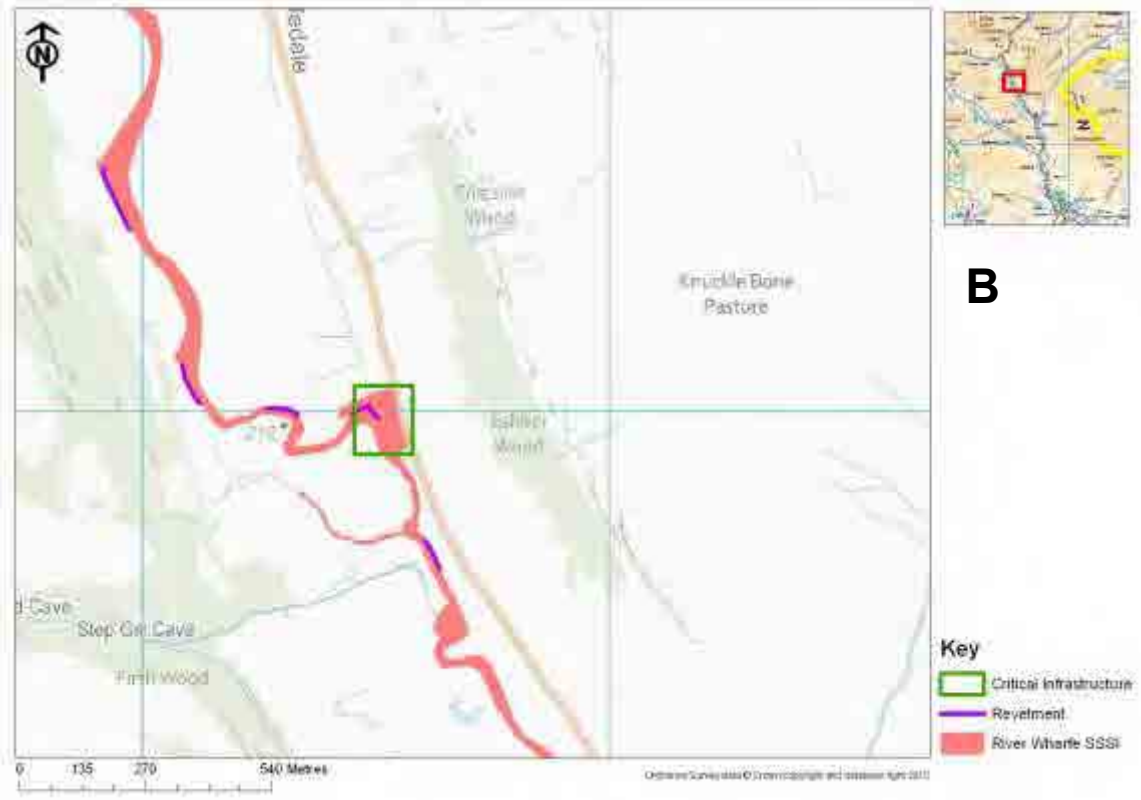
Figure 4-3 Location of significant channel straightening along the River Wharfe SSSI (maps A and B).

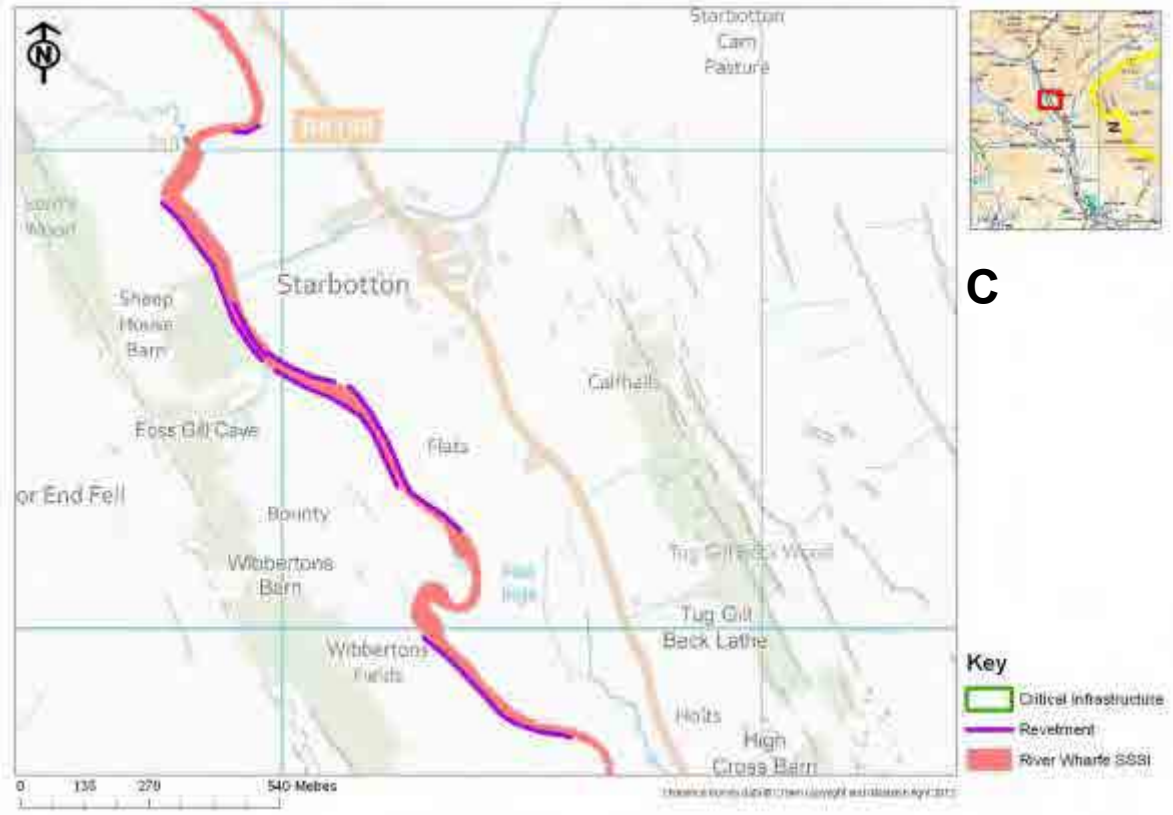
4.1.5 Channel training

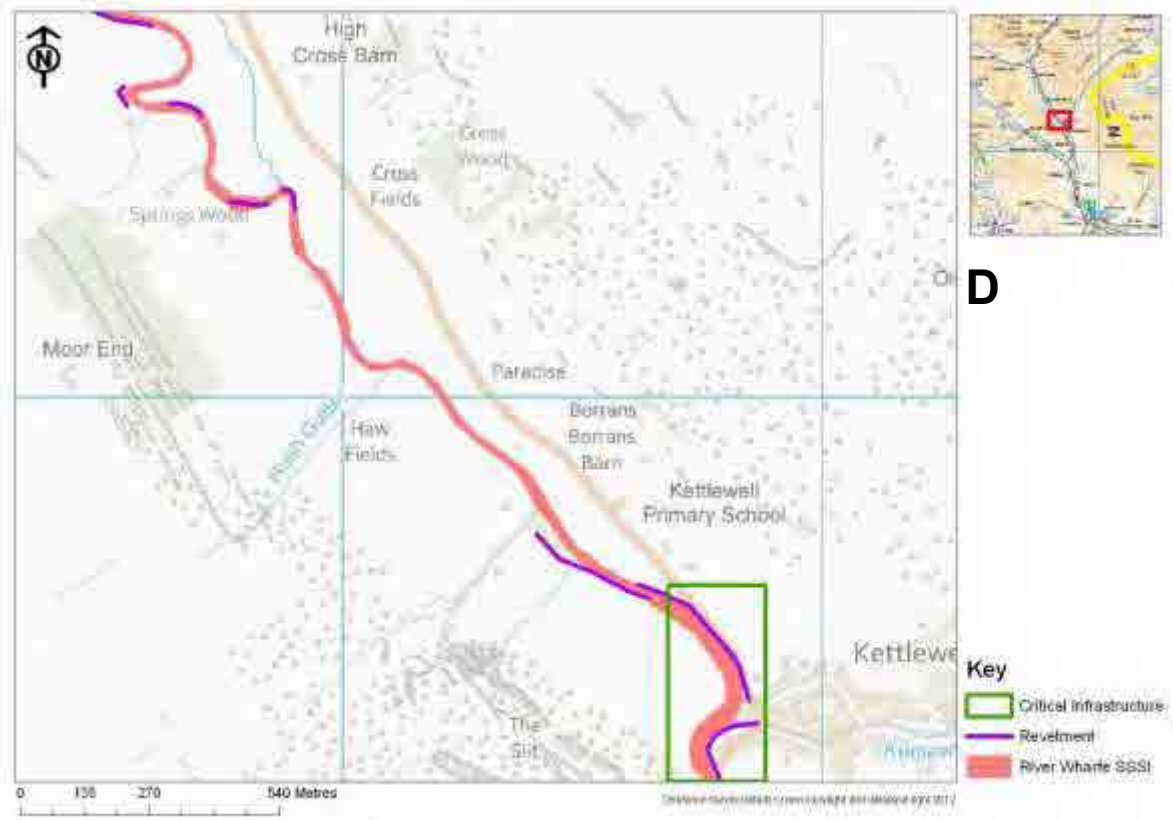
Bank revetment, which is a form of channel training, is extensive along the river in various forms ranging from walling to blockstone. Reduced channel maintenance means that areas of historic protection are now failing (Figure 4-3). Many opportunities exist to remove revetment, however, channel response in the form of lateral erosion and flood frequency is likely and must be planned for. There will be a need for bank revetment to remain where it protects infrastructure (roads etc) and buildings, and to agree appropriate maintenance. These areas are shown in green in Figure 4-4 A to F below. The potential historic environment importance of the historic walling should also be recognised and the impact of any removal assessed.

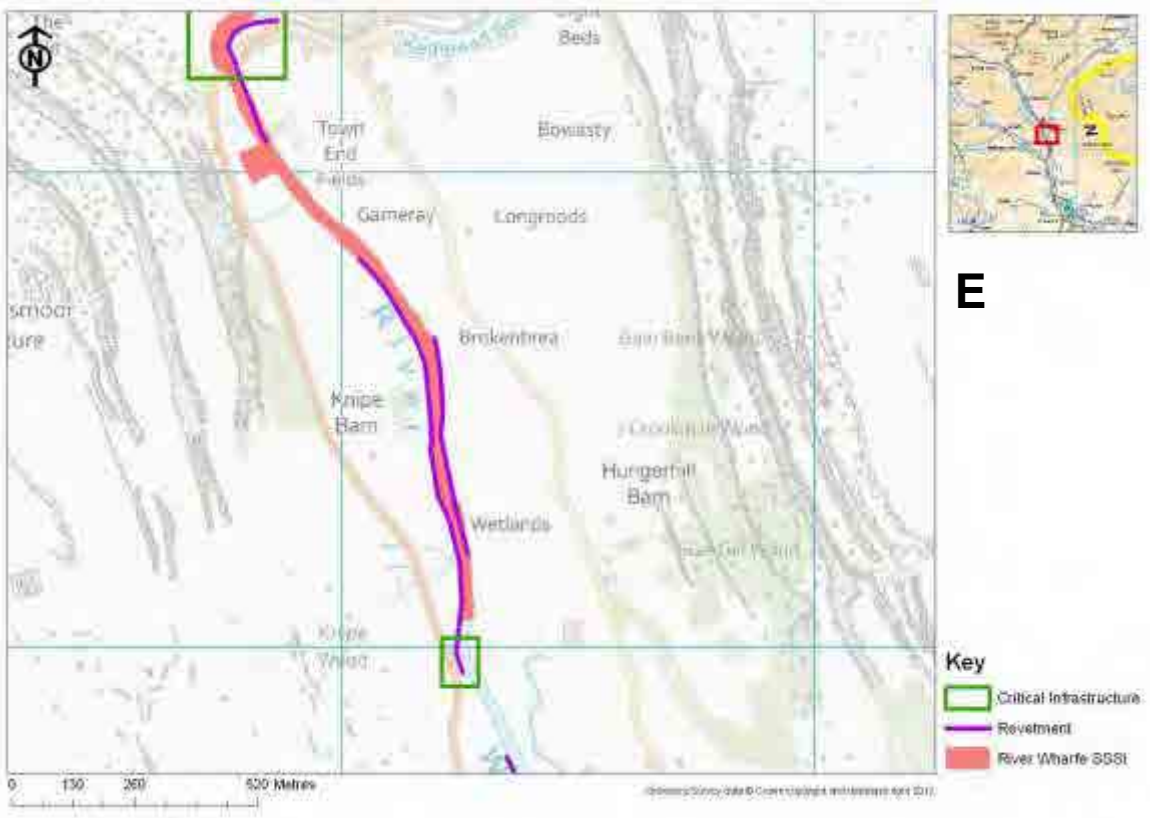
Figure 4-4 Location of channel revetment along the River Wharfe SSSI (maps A to F).

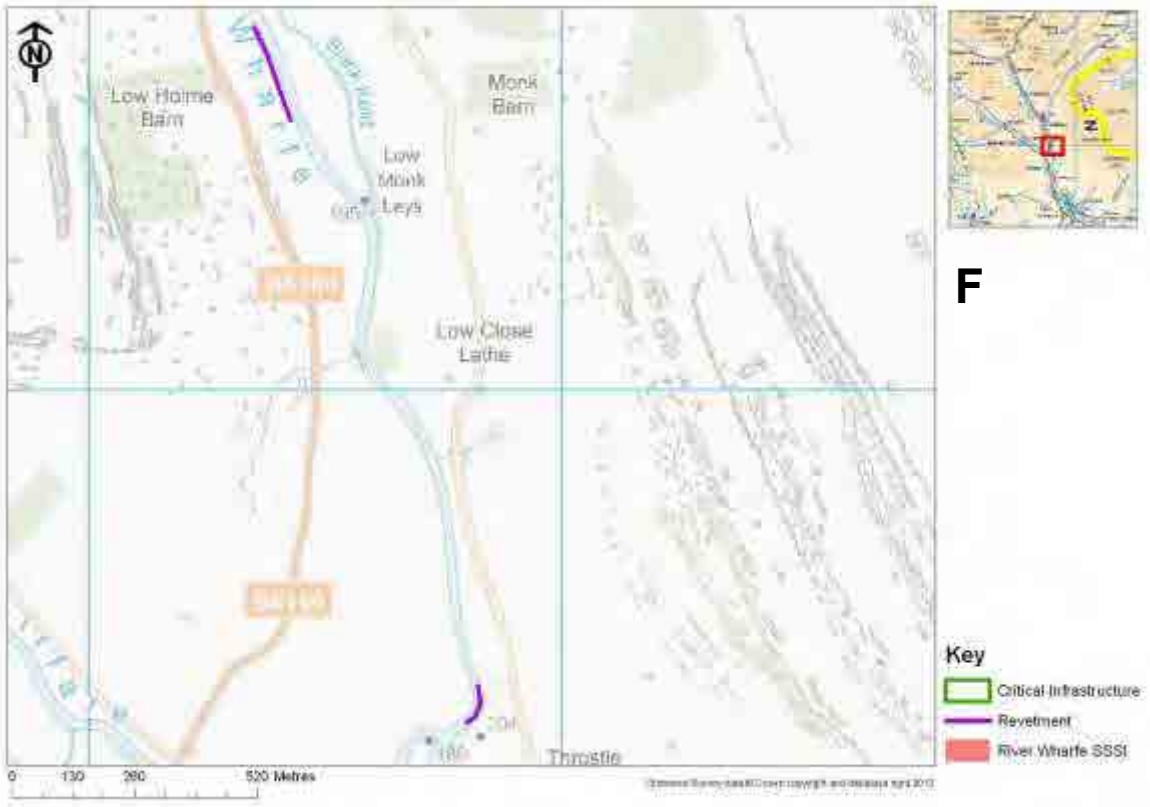





Starbotton
Cam Pasture
Starbotton
Sheep House Barn
Foss Gill Cave
Bounty
Wibbertons Barn
Wibbertons Fields
Calfhalls
Flats
Tug Gill Back Lathe
Holts
High Cross Barn
or End Fell
0
135
270
540 Metres
C
Key
Critical Infrastructure
Revetment
River Wharfe SSSI


High Cross Barn
Cross Fields
Moor End
Paradise
Borrans
Borrans Barn
Haw Fields
Kettlewell Primary School
Kettlewe
0
135
270
540 Metres
D
Key
Critical Infrastructure
Revetment
River Wharfe SSSI





4.1.6 Gravel removal

The River Wharfe has a long history of gravel shoal removal, principally to increase channel capacity and reduce flooding frequency. Coarse gravels enter the channel via tributary gills which are cutting down in to deposits on the terraced hillslopes. The reach of the river upstream of Starbotton is particularly prone to sediment accumulation as a result of a historic landslide in the 1600's which prevents sediment movement downstream. As a result of the sediment

accumulations the river has adjusted. This has taken the form of increased bed levels and bank erosion. Historically, this problem has been managed by gravel removal, the most extensive recent programme occurred in the 1980s where shoals were reduced along the Wharfe, particularly between Hubberholme and Kettlewell as part of the Buckden Flood Alleviation Scheme (Figure 4-5).

Figure 4-5 Locations of gravel removal as part of the during the Buckden Flood Alleviation Scheme during the 1980's

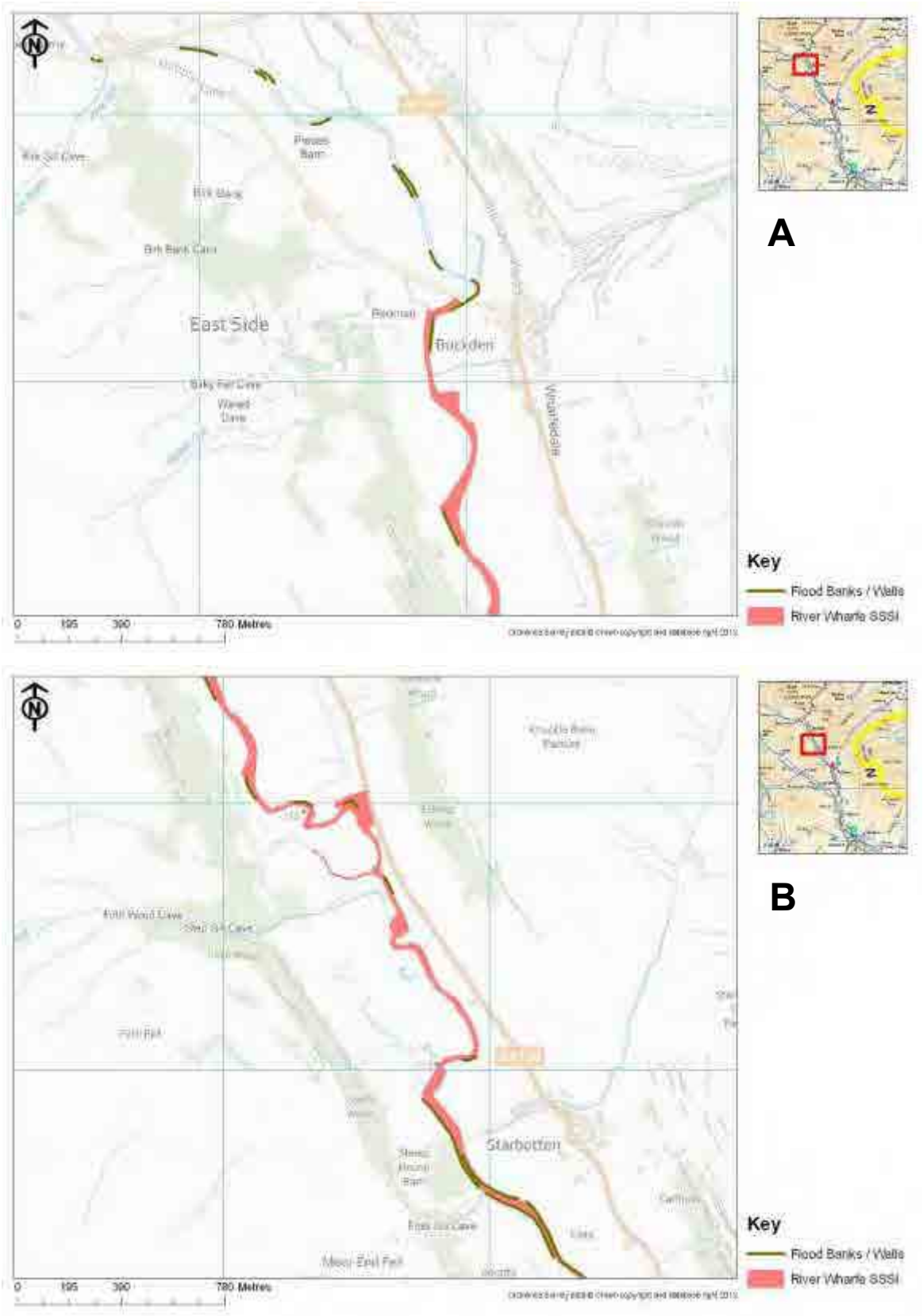
Many of these features have returned or are returning and much of the current gravel shoaling and bank erosion activity can be attributed to historic gravel removal. Where feasible no further gravel should be removed from the river. This will also ensure fish spawning areas are protected. In all cases it is hydromorphologically detrimental to remove gravel from the active transport system as it disrupts system morphology and transport continuity, impacts on in-channel habitats, alters the frequency and extent of natural overbank flooding and temporarily elevates fine sediment levels during removal impacting on downstream gravel integrity. Should flood risk considerations override hydromorphic disruption then all removed material should be reintroduced to the system as close as possible downstream where flood risk is not an issue avoiding local system overloading and ensuring that it is assimilated into the natural transport regime with the minimum of local disruption

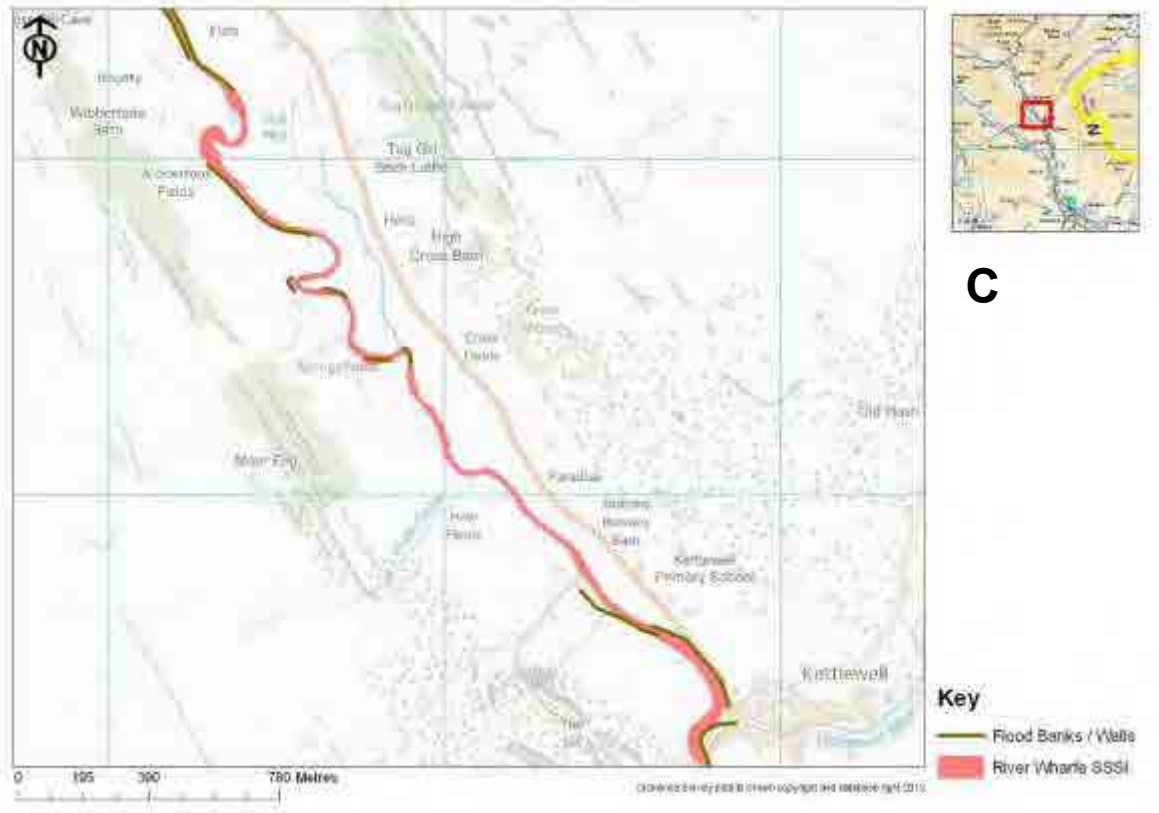
Groundwater levels will also have been lowered due to the bed degradation further disconnecting floodplain palaeo-features and impacting on floodplain habitats.

4.1.7 Flood banks

Low adjacent flood banks occur extensively along the SSSI (Figure 4-6) retaining flood flows in the channel. Many flood banks were installed by predecessors to the EA during the 1980's. Currently, flood banks along the upper Wharfe are not maintained. These flood banks have caused channel incision by confining higher energy in channels flows. As a result the bed of the river is now seriously disconnected due to erosion from the floodplain along many reaches. As this erosion continues the risk of embankment failure increases. Often when embankments fail floodwater can become trapped on the floodplain as it is unable to quickly drain back into the river when levels drop. Whilst flood banks have enabled grazing alongside the river in many fields it has reduced the wetland habitat within the floodplain.

Figure 4-6 Location of flood banks along the River Wharfe SSSI (maps A to C)





4.1.8 Floodplain management

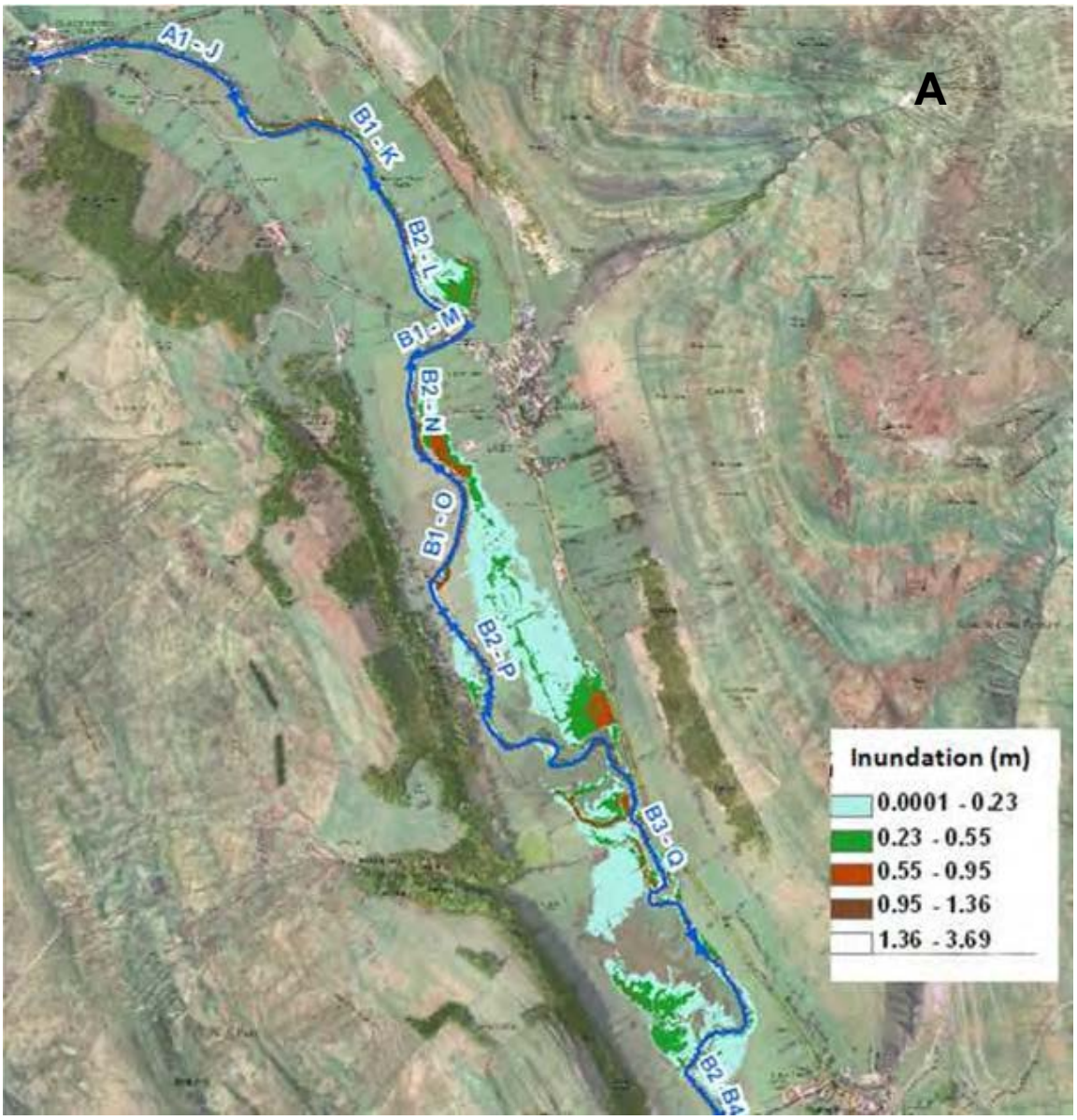
Current and historic floodplain farming practices have significantly altered the natural habitats and vegetation on the floodplain, with riparian character seriously altered. Much of the floodplain is now semi-improved neutral grassland, often of limited species-richness or heavily improved pasture, with only limited areas of wetland vegetation (e.g. rushy pasture, pools, sedge beds, wet grassland). Remnant riparian woodland is non-existent and much of the river bank is characterised by mature single trees (Sycamore, Alder, Ash).

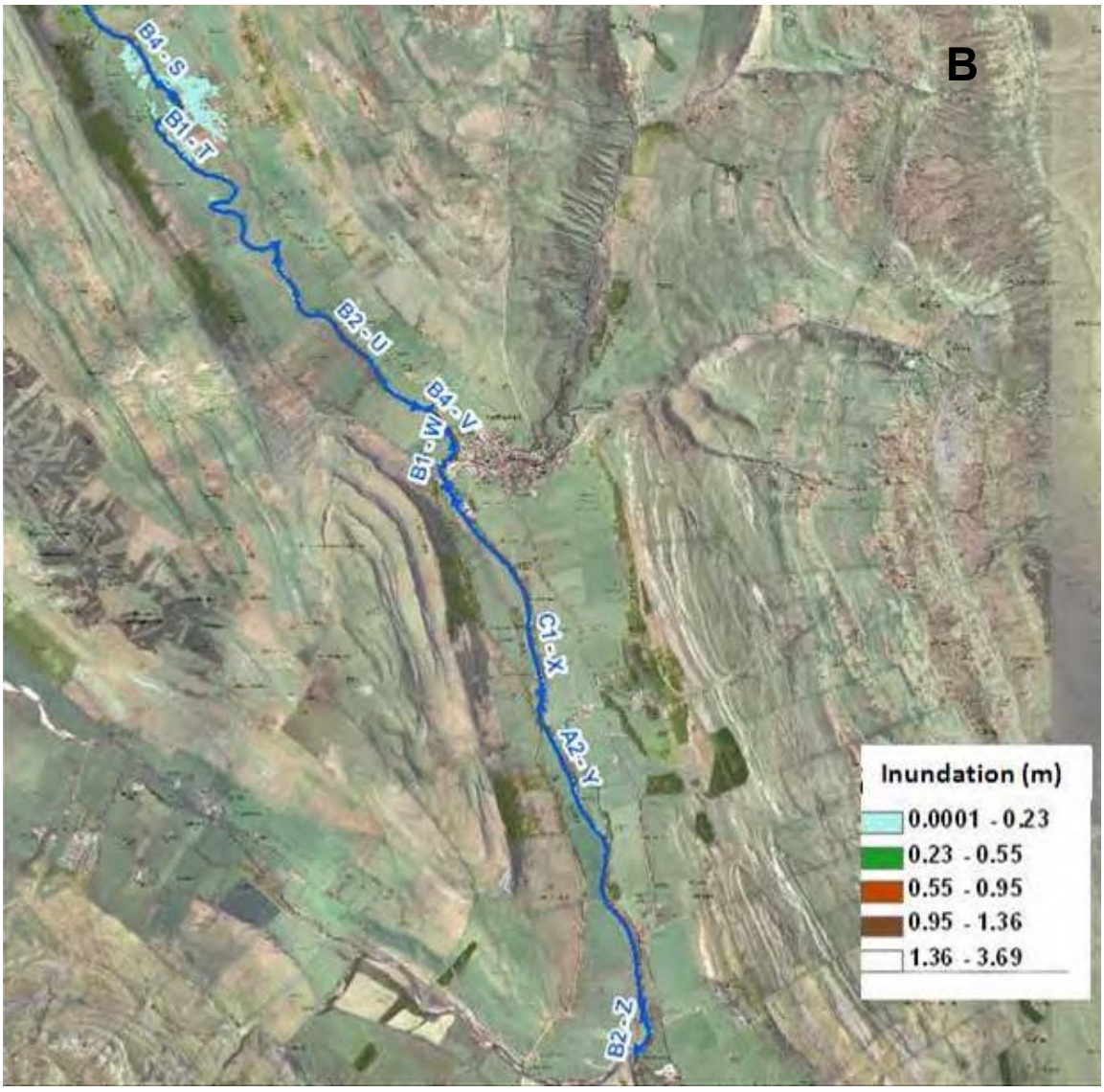
Recent initiatives to fence the bank edge and to plant Willow species is improving the situation and helping to control fine sediment inputs from the floodplain, although in places recent tree planting has been inappropriate, with unsuitable species (e.g. Sycamore) and in inappropriate locations (e.g. species-rich meadows and wetlands).

4.1.9 Limited connection between floodplain and river

The connectivity between the river and the floodplain is poor through the SSSI with the flood inundation and groundwater regime adversely affected. There are several factors which contribute to the limited floodplain connection (as discussed above), including flood defences and embankments and historic gravel removal. Figure 4-7 displays out of bank flow paths (some following the original course of the river prior to historic modification). This hydraulic modelling helps inform and points towards areas of possible reconnection opportunities, discussed in Section 5. A detailed explanation of the hydraulic modelling can be found in Appendix 2. Any potential changes in floodplain connectivity would need to be agreed with landowners and further feasibility work will need to be undertaken, with appropriate support in place e.g Environmental Stewardship

Figure 4-7 Local floodplain connectivity opportunity areas through the River Wharfe SSSI.





4.1.10 Wider catchment issues

The upper catchment is dominated by forestry and moorland, giving way to improved pasture as the floodplain widens downstream of Hubberholme. Generally the landscape is stable, however, significant point sources of coarse sediment exist associated with erosion of till deposits along upland gills. These include:

- soil creep processes slowly moving valley side till towards the headwater delivery channels
- erosion of valley side till with associated downslope transport
- erosion of previously deposited fluvio-glacial deposits in upland valley's
- erosion of previously deposited fluvial berms along upland gills
- downstream movement of stored coarse sediment in upland watercourses

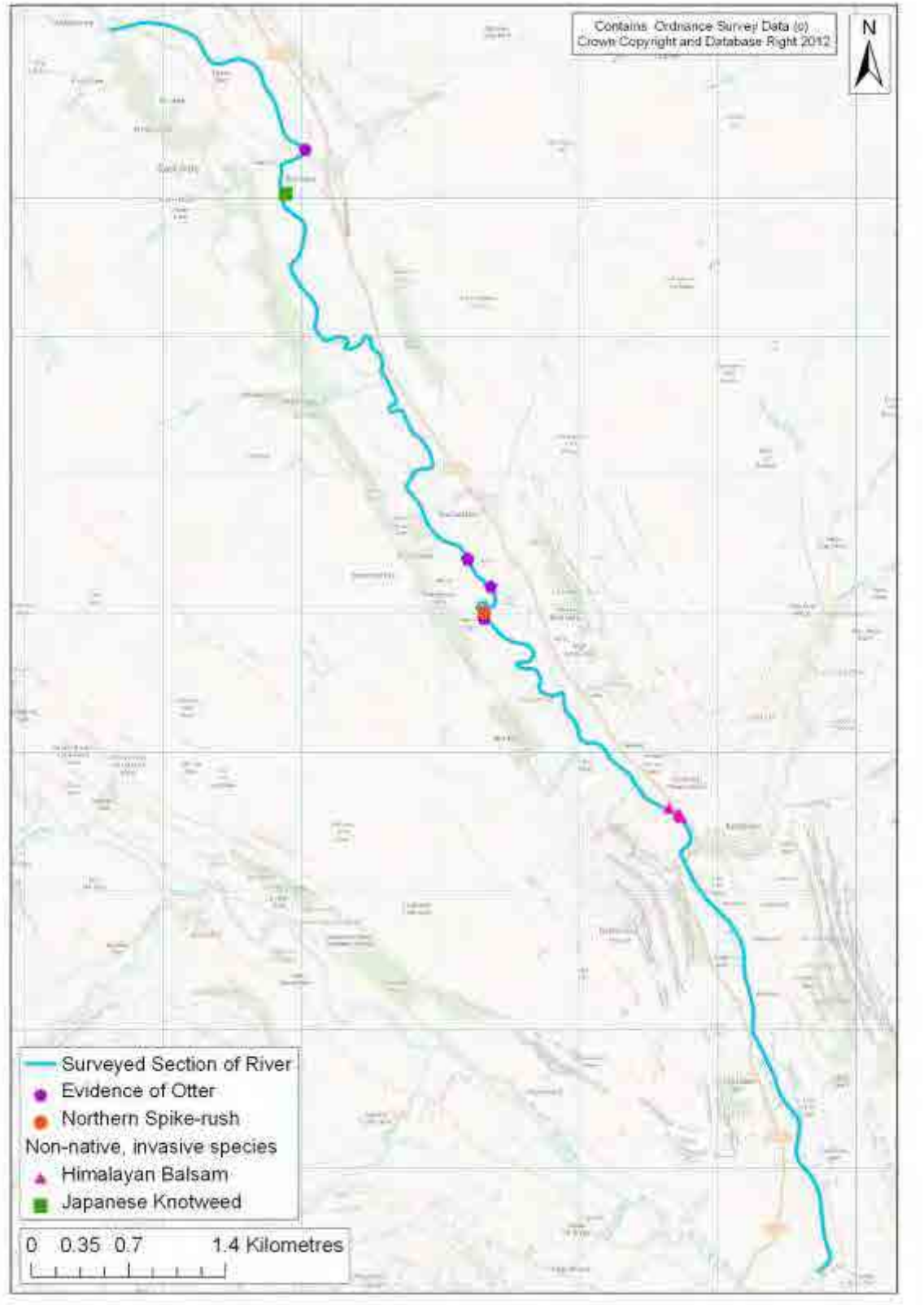
A futher problem which has been identified, is moorland gripping. This was undertaken during the 1960's, 1970's and 1980's to improve drainage. As a result of this the run off from the moorland areas occurs more rapidly, resulting in a much quicker time to peak for the Wharfe.

4.1.11 Invasive species

Several non-native invasive plant species were encountered during the survey, as discussed above. This included one patch of Japanese Knotweed at the confluence of Buckden Beck and several patches of Himalayan Balsam just upstream of Kettlewell. North American Signal

Crayfish are believed to be present throughout the surveyed reach of the Wharfe, and also potentially the larger tributaries. This was evident by the large quantity of crayfish remains (believed to be Otter feeding remains) recorded throughout the reach. Four live animals were also noted in the river from Starbotton Bridge.

Figure 4-8 Protected / Notable and Invasive species recorded along the Wharfe



4.1.12 Climate Change

UKCP09 predictions for the North of England under medium emissions scenario with 50% confidence suggest an overall 15% decrease in summer flows for the period 2050-2079 over the 1961-1990 average. Winter precipitation is predicted to increase by 10% under the same criteria. Despite the inherent uncertainty behind these predictions reductions in summer baseflows and increased winter high flows are likely to impact on channel hydromorphology and dynamics.

Summer baseflow reduction impacts are likely to include:

- Lowered hydraulic habitat diversity
- Increased water temperatures
- Increased risk of summer no-flow conditions
- Ingress of fine sediments into the coarse bed leading to choking
- Reduce marginal habitat extent and variability

Winter High flow increase impacts are likely to include:

- Increased frequency of geomorphologically effective flows
- Increased gravel transport
- Increased bank erosion associated with channel planform and gravel deposition
- Probable remobilisation of fines stored in the channel bed
- Potential bed armouring
- Development of wandering channel reaches
- Potential loss of adjacent flood bank
- Reduction in lower energy hydraulic refugia potentially offset by creation of new areas.

The river is energetic and will respond to precipitation induced flow regime changes, adapting its morphology to the altering flow regime where it is not constrained. These adaptions are likely to result in an increase in wandering channel behaviour and the development of a long term armoured bed subject to fine sediment infilling in the summer but moderated by inputs of gravels as a result of heightened erosion and increased upper catchment source release.

4.2 Pressures on the River Summary

Table 4-1. Summary of key pressures along the River Wharfe

Pressure	Consequence	Example
Bed Erosion and Bank Instability The effects of bed lowering through repeat dredging has encouraged in-channel bed erosion and bank instability	Livestock have utilised the collapsed banks to gain access to the river in a number of locations leading to enhanced erosion of the banks (poaching). Increased input of fine sediment into the channel which leads to increased in channel siltation. A more uniform channel reduces the habitats within the river (i.e. fewer refuges for shelter). Limited bankside vegetation due to erosion and as a result a decline in habitat.	
Flood Embankments Flood banks have caused channel incision by confining higher energy in channels flows.	The bed of the river is now disconnected (due to incision) from the floodplain along many reaches. As this erosion continues the risk of embankment failure increases. If embankments are overtopped flow can become trapped behind them.	
Lack of Trees Several reaches have poor riparian vegetation cover compared to the typical natural landscape of the area and what would provide a good riparian condition	Limits the amount of woody debris entering the channel which limits the cover for fish and creates less habitat diversity Banks will become more vulnerable to erosion. Remnant riparian woodland is non-existent and much of the river bank is characterised by mature single trees (Sycamore, Alder, and Ash).	

Pressure	Consequence	Example
Floodplain Management Current and historic floodplain farming practices have significantly altered the natural habitats and vegetation on the floodplain, with riparian character seriously altered.	Much of the floodplain is now semi-improved neutral grassland, often of limited species-richness or heavily improved pasture, with only limited areas of wetland vegetation (e.g. rushy pasture, pools, sedge beds, wet grassland). Remnant riparian woodland is non-existent and much of the river bank is characterised by mature single trees (Sycamore, Alder, Ash).	
Invasive Species Japanese Knotweed at the confluence of Buckden Beck and several patches of Himalayan Balsam just upstream of Kettlewell have been noted. North American Signal Crayfish are believed to be present throughout the surveyed reach of the Wharfe, and also potentially the larger tributaries.	Die back of invasive species during winter months leaves banks exposed and prone to erosion Quickly spread and can lead to a decline in native species	
Lack of Floodplain Connectivity Several factors contribute to this including embankments concentrating in channel flows and gravel removal increasing incision	A reduction in the frequency of floodplain connection means that fine sediment is deposited within the channel and not on the floodplain. Too much fine sediment in the channel can effect and reduce spawning habitats.	

Pressure	Consequence	Example
Channel Training Bank revetment, which is a form of channel training, is extensive along the river in various forms ranging from walling to blockstone.	Reduced channel maintenance means that areas of historic protection are now failing and the channel response in the form of lateral erosion must be planned for.	
Flow Regime Alteration The rivers flashy flow regime has been intensified by moorland gripping in the upper catchment.	Moorland gripping has led to increased run off and fine sediment input.	
In Channel Structures Weirs and culverts can impound the river increasing water levels upstream and disrupt sediment continuity.	There is a reduction in flow depth variation and velocity as a result of structures being in place. Fish passage is reduced / prevented and the range of habitats is reduced.	

Pressure	Consequence	Example
Channel Realignment In some areas the channel may have been straightened	The river has responded to straightening by cutting down into the bed rather than by eroding laterally due to the presence of revetment.	
Climate Change Predicted decrease in summer precipitation and increase in winter baseflow.	Summer baseflow reduction impacts are likely to include, lowered hydraulic habitat diversity, increased water temperatures, increased risk of summer no-flow conditions, ingress of fine sediments into the coarse bed leading to choking and reduce marginal habitat extent and variability Winter High flow increase impacts are likely to include, increased frequency of geomorphologically effective flows, increased gravel transport , increased bank erosion associated with channel planform and gravel deposition, probable remobilisation of fines stored in the channel bed, potential bed armouring, development of wandering channel reaches, potential loss of adjacent flood bank and reduction in lower energy hydraulic refugia potentially offset by creation of new areas.	

4.3 The next 50 years - the need for restoration

The River Wharfe is a dynamic river system that has been impacted by historic and current alteration and management (dredging, indirect flow regime change, straightening, embanking, revetting and floodplain use). Under a likely scenario of reduced channel maintenance (flood bank and revetment) and increased winter flow discharges due to a changing climate a number of aspects of the river character are likely to change over the next 50 years (without restoration). These are predicted below.

4.3.1 Increased development of large exposed gravel bars

Increased winter flow levels and available energy to erode and transport gravels will favour the development of wide gravel shoals and bars along moderately steep reaches where bank revetment is not preventing lateral erosion. River styles similar to that seen below Buckden will increase along the river.

4.3.2 Increased incidence of severe local erosion

Failing revetment is acting as a focus for river bank erosion and local gross change to the river cross-section. Flood flows are outflanking engineering works at weak points. More of these weak points will be exploited as revetments deteriorate naturally and winter flow levels increase available erosive energy.

4.3.3 Heightened lateral erosion threatening flood protection

The floodplain of much of the River Wharfe through the SSSI is liable to erosion due to the uncohesive nature of the bank sediments and the lack of riparian and floodplain woody vegetation helping to stabilise the channel margins and failing bank protection. As such lateral channel movement will increase over time and flood banks local to the present watercourse will be eroded and may fail leading to local breaching of the defences. Flood waters are likely to be retained behind embankments due to blocked return flow routes.

4.3.4 Selective loss of isolated bankside trees

The intensively managed floodplain has restricted woody vegetation to isolated single lines of bankside trees. Many of these were planted over a century ago, probably along much longer continuous reaches of the river, but over time have been lost through a variety of factors. It is increasingly likely that isolated trees and stands will be under greater threat of erosion as overall root cohesion is reduced and winter flows increase. This will change the riparian character and will also introduce woody debris into the channel.

5 System Naturalisation Opportunities

5.1 Overview

In England, the river restoration programme for Site of Special Scientific interest (SSSI) rivers has highlighted the need to develop appropriate funding mechanisms to incentivise river restoration. The SSSI river restoration plan for the Wharfe sets out restoration actions to contribute to achieving favourable SSSI condition, and potentially can also provide sustainable flood and erosion risk management benefits.

The risks caused by the historic and current management of the Wharfe, and a potential "room for the river", or "making space for water" restoration approach is illustrated in the section below. Where critical infrastructure is a constraint, a similar "erodible corridor" approach may be taken. The erodible corridor concept "consists of defining a corridor in the alluvial floodplain, within which decision-makers will not seek to control erosion using engineered protections. At its simplest the concepts tries to balance the environmental benefits of allowing the river to move freely (within the corridor), and allowing sedimentary processes to occur and the economic benefits derived from protecting property and infrastructure (outside the corridor"1.

Room for the river type approaches to flood and erosion risk management and habitat restoration are increasingly being used across continental Europe, including a national programme in Holland, and on powerful rivers such as in the Rhine, Meuse, Danube and Loire, primarily as a way to manage flood risk.

The River Wharfe is an inherently reactive system which is still adjusting to historic modification (section 2.3). As such restoration measures will result in river response. These reflect the naturalisation process being encouraged by the restoration plan. Some responses will see increased channel lateral activity and heightened erosion and deposition. There is an important requirement to ensure that this is recognised by all stakeholders and that on the ground compromises linked to current river and floodplain utilisation do not compromise the overall success of the naturalisation process.

The in-channel hydromorphic condition of the River Wharfe is generally very good with the channel displaying an open cobble/gravel bed with strong evidence of active coarse sediment transport. Aquatic in channel vegetation is generally low and is dominated by aquatic mosses, although increased diversity was noted in the stagnant backwater areas. There are several areas of lower quality channel linked to historic channel engineering and management and contemporary land use issues. The floodplain associated with the SSSI River is in a very poor state and is currently non-functional due to engineered disconnectivity. The following section presents some preliminary ideas on small scale and large scale hydromorphic and ecological improvements that can be made along the River Wharfe SSSI that will address the system pressures and promote system naturalisation.

Within the Wharfe, the pool-rapid type VIIIe has been developing under current catchment controls and are presently functioning well. Despite this the SSSI condition assessment noted that the river reach was still characterised by vegetation of type Va. It is anticipated that as coarser cobble / boulder habitats develop they will be utilised by species more associated with this type of feature.

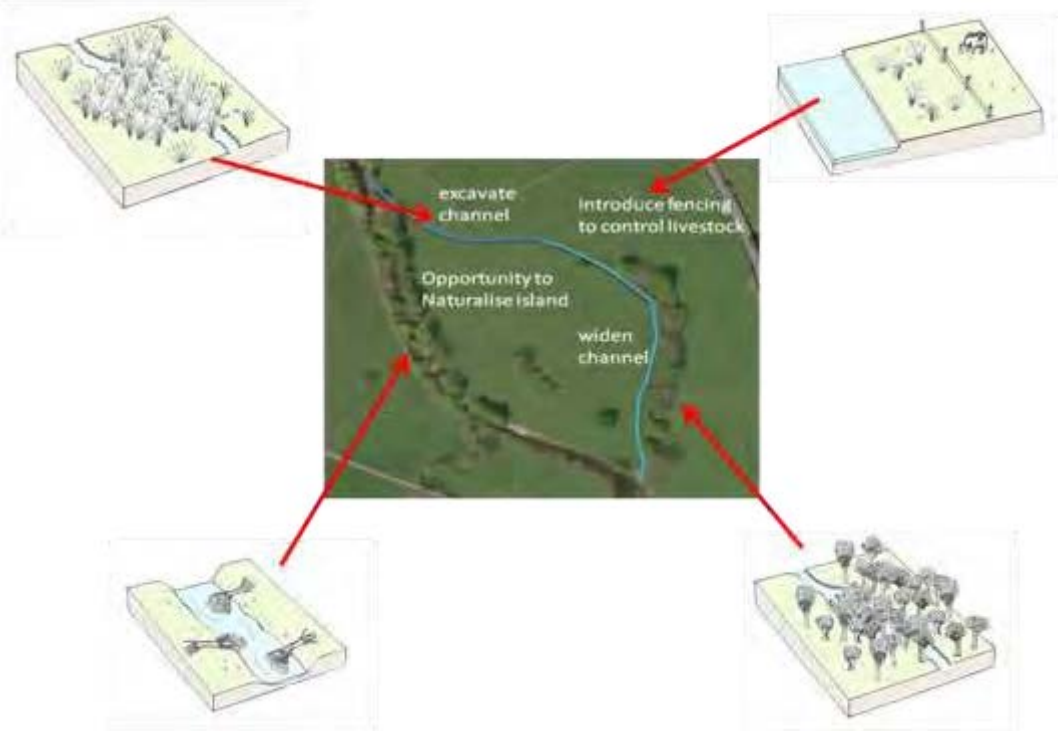
Any potential changes in land use and floodplain connectivity would need to be agreed with landowners, with appropriate support in place e.g Environmental Stewardship. In a number of locations there is a need for modifications to remain to protect where people, infrastructure and buildings from flood risk and excessive erosion.

5.2 Restoration Options

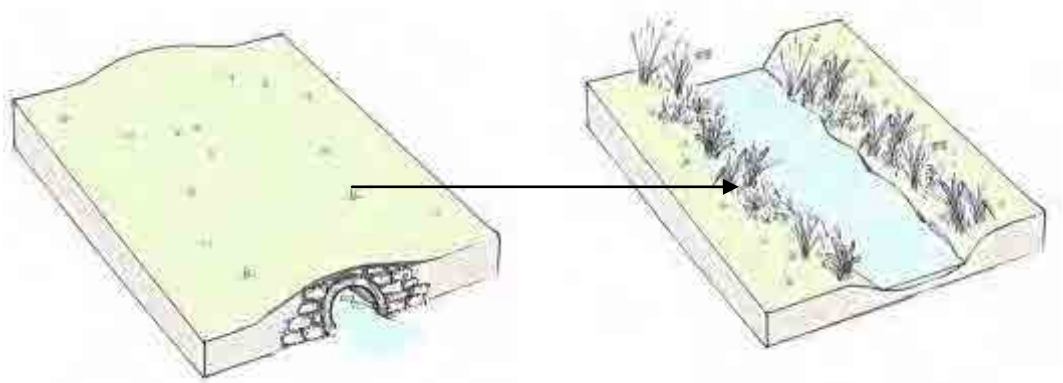
To restore the river channel to the condition described in the restoration visions, a series of restoration measures are suggested. These fall into two categories, large and small scale.

All measures involve riparian and floodplain naturalisation. No enhancement or restoration actions will be undertaken without consultation and agreement with the appropriate landowners and other relevant stakeholders. Any increase in flood risk will need to be quantified before any restoration works are carried out.

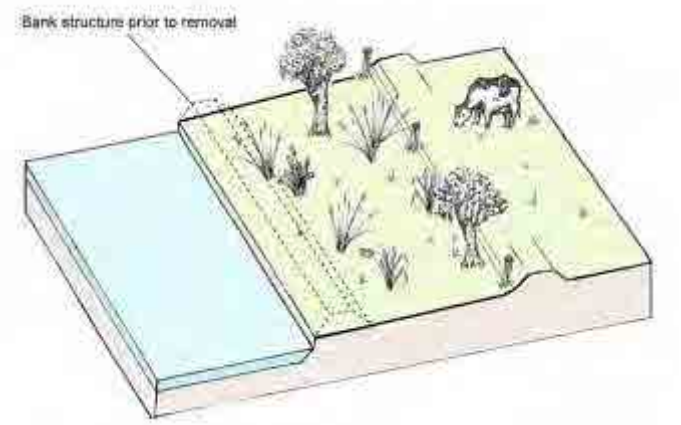
The following section describes the range of measures that could be implemented to enhance or restore the morphology of the River Wharfe SSSI so that the channel morphology is consistent with favourable condition.

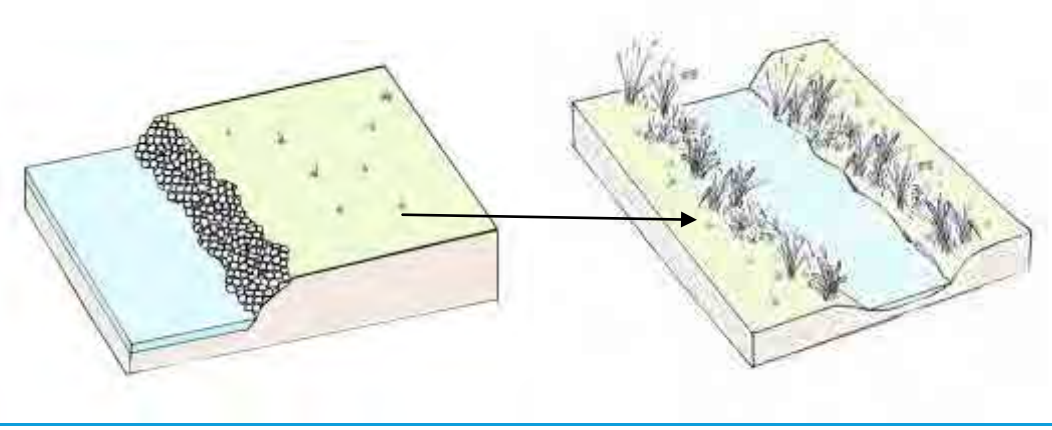
Paleo-Channel Reconnection **Description: Permanent connection of old palaeo channels to the river by excavating new channels and reconnecting**	
Benefits	Constraints
• Creation of high flow secondary channel with associated habitats. In terms of fisheries these will be particularly valuable for juvenile life stages during normal flows. • Reduced energy in main channel leading to development of gravel features and eroding banks. Increase in prevalence of gravel features in main channel likely to provide spawning opportunities, as well as providing more abundant prey species habitat. • Opportunity to naturalise floodplain 'island' and introduce varied wetland, grassland and woodland habitats with consequent increase in diversity and abundance of invertebrate prey species. • Creation of temporal and habitat variety across the floodplain. • Improved local flood capacity. •	• Short term disruption to gravel transfer downstream may cause bed disruption, but unlikely to result in significant impacts, when undertaken with appropriate mitigation. • Minor, localised disturbance to species and habitats during works. • Some land loss in order to control livestock
	

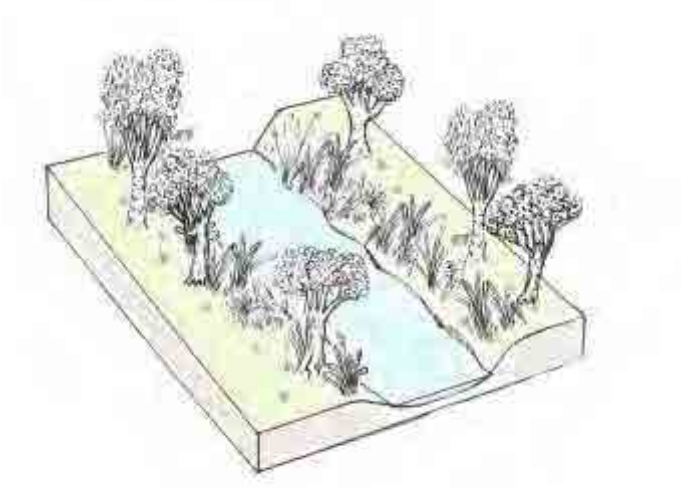
Tributary Junction Development Description: Setting back of flood embankments, controlling livestock access to encourage a more naturalised tributary junction	
Benefits	Constraints
• Further development of well connected morphology and ecology, including several bars. • Setting back embankments and increasing floodplain connectivity should promote diversity and extent of riparian habitats and associated invertebrate communities and therefore an increase in abundance of prey species • Wetland habitat creation at tributary junction through increased inundation. • Development of tributary junction likely to provide diverse flow regimes and in channel diversity.	• Minimal release of sediment during works. This will be rapidly assimilated into the transport regime and will have minimal impact on fisheries. • Minor, localised disturbance to species and habitats during works. • Potential for rank, disturbance-tolerant vegetation to develop if inundation is infrequent or compaction occurs during works • Braided channel and consequent reduction in channel depth may reduce accessibility to tributary for larger adult fish • Some land loss in order to control livestock
	

De-Culverting Description: The removal of underground culverted sections of channel and the restoration of open water reaches	
Benefits	Constraints
• Removal of behavioural (and potential physical barrier) to lateral migration will allow exploitation of tributary by all life stages. • Potential to create new in-channel and riparian habitat and will reinstate open channel habitat and will likely result in more diverse and utilisable habitat benefitting all life stages. • Potential enhancement of wetland habitats (e.g. rushy pasture) upstream of culvert through increased connectivity with main river.	• Minimal release of sediment during works. This will be rapidly assimilated into the transport regime and will have minimal impact on fisheries. • Minor, localised disturbance to species and habitats during works.
	

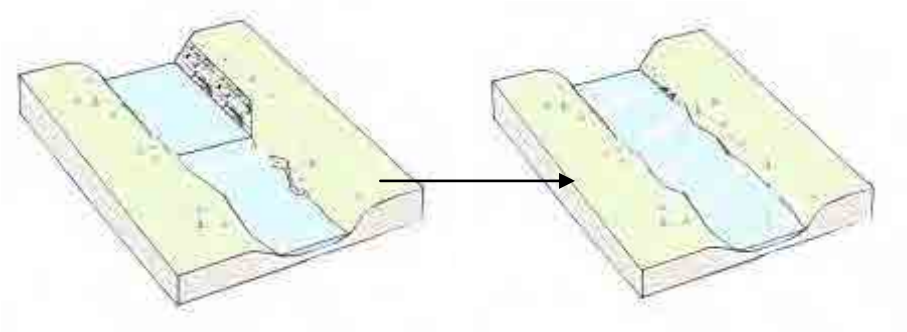
Removal / Setting back Flood embankments Description: The removal of flood embankments to allow the natural inter-relationship between the river channel and the floodplain to be reinstated	
Benefits	Constraints
• Provides connectivity between the river channel and the surrounding floodplain reducing flood impacts downstream. • Limits the impact of flood flows on the river channel by allowing water to dissipate beyond the channel rather than remaining within the channel. • Allows the deposition of fine sediment onto the floodplain thereby reducing the likelihood of the deposition of fine sediment within the river channel. • Improves drainage of the floodplain by allowing surface water to drain freely into the river channel. • Removes the risk of catastrophic failure of the embankment where the river bed has aggraded between the embankments	• Will increase the frequency of floodplain inundation which may necessitate changes in farming practices on the floodplain. • Will generate a large amount of spoil which will need to be disposed of in an appropriate manner. • Potential to impact on upland farming system.

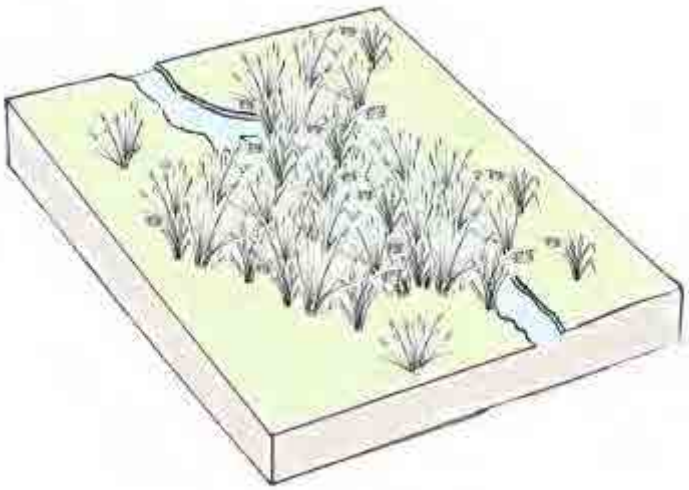


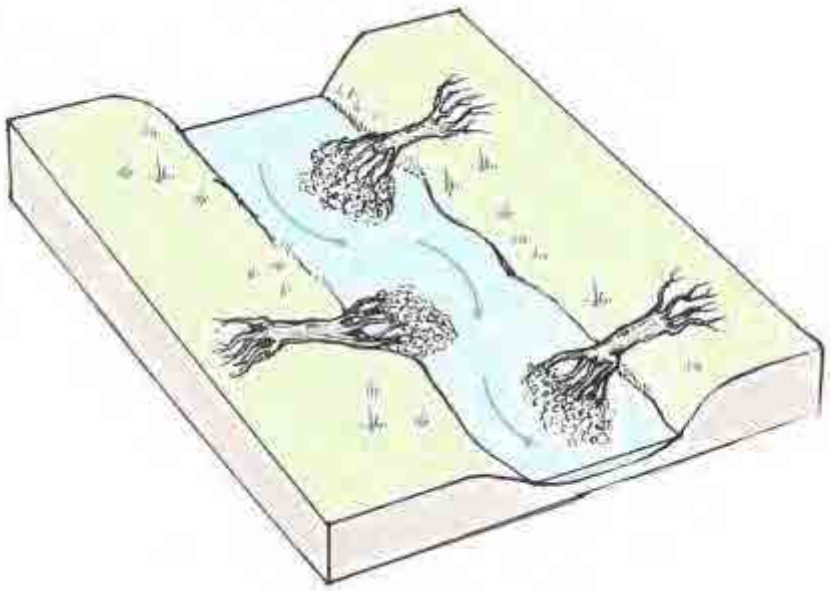
Removal of Bank Toe Protection Description: The removal bank reinforcement is essential for allowing a section of river channel to develop a natural channel morphology which is able to adjust to changes in flow and sediment supply	
Benefits	Constraints
• Allows natural bank materials to be exposed. • Enables a natural channel planform to develop via bank retreat. • Enhancing natural bank profiles will support a more diverse range of habitats for many species, including potentially undercut banks and naturally vegetated banks (fish spawning and juvenile habitat). • Allows the river channel to undergo natural morphological change in response to changes in flow and sediment supply. • Enables more varied channel morphology to develop through bank erosion and changes in bank profile	• Requires works within the river channel and may result in a period of disturbance to channel and riparian areas. • Channel migration may impact on services which cross the floodplain such as drains, water mains, electricity cables (above or below ground) and gas mains. • Short to mid term sediment release and potential impacts on sensitive locations. • Some land owners will lose land.
	

Enhancement of riparian Vegetation Description: The riparian zone refers to the strip of land, typically floodplain, immediately adjacent to the river bank top. The recovery of the riparian zone may be achieved by creating a strip of undisturbed ground along the river channel and allowing vegetation to re-colonise naturally. The intention is not to create an entirely wooded corridor but to create a more varied corridor where land use pressure is reduced	
Benefits	Constraints
• Reducing livestock access will reduce bank erosion and allow re-colonisation of macrophytes within the channel, which in turn will provide habitat for fish and macroinvertebrates, and potentially spawning habitat for fish. • Riparian vegetation will also increase water quality (as a filtration system for run-off), and in-channel macrophytes may act as a trap for sediment. • Limiting siltation along channel margins and in areas of slow flow such as pools and backwaters; • The retention of woody debris in streams will provide preferential habitat for species such as fish and invertebrates • Bankside vegetation creates diversity in shading and cover important for juvenile fish • Bankside trees and dense vegetation can provide habitat for otters and bats.	• Farm land loss
	

Chute Channel Creation Description: The creation of high flow meander cut offs will offer flow variability and allow the river to migrate	
Benefits	Constraints
• Approach works with the current point bar morphology and processes operating as part of the chute channel cut-off process leading to channel isolation and abandonment. • Enhancement of high flow chute channel will divert low and medium flood flow and associated erosive energy away from the outer bend. • High flow 'chute' will provide new periodically wet habitat, and increase habitat diversity across the immediate riparian zone. • Potential for creation of more 'natural' habitats over the more isolated bar surface created behind chute channel. • Retention of valuable deeper pool refuge and feeding station habitat, likely to be exploited by larger adult fish, on meander bend. Development of diversity of morphological features will provide increased habitat and flow diversity exploitable by all life stages.	• Likely to cause longer term channel adjustment up and downstream but this mimics natural cut-off process. • Minor, localised disturbance to species and habitats during works. • Natural maturation of point bar features will be disrupted. However, retention of diverse habitat promoted by this proposal will likely outweigh any limitation associated with natural development of backswamp/oxbow feature. • Some land loss along riparian margin. • Potential spread of non-native invasive plant species.
	

Weir Removal **Description: Weirs create carriers to downstream passage of flow and sediment and frequently upstream passage of fish. Removal of weirs may involve removing the structure (wing-walls and bed stones) and bank lowering or widening (re-profiling) to help the channel re-establish a more natural form;**	
Benefits	Constraints
• Allows more natural water level variations upstream (reduces deep water from impoundment); • Enables natural downstream sediment transport and reduces upstream silt smothering of river bed caused by impoundment; • Allows the development of more varied flow types upstream of the former structure, increasing habitat variety including potential areas suitable for *ranunculus* and other macrophytes; • Allows the river channel morphology to respond and adjust to changes in flow and sediment supply, creating diverse channel morphology; • Removes barriers or obstacles to fish movement through the river system between suitable local habitats	• Further feasibility work is recommended before any weir removal to investigate up and downstream impacts. • Weir removal can be undertaken in conjunction with bank re-profiling, installing woody debris and riffle creation to maximise morphological improvements.
	

Wetland Creation **Description: The creation of wetland areas provides links between aquatic and terrestrial habitats. This can be achieved by lowering banks to widen small tributaries or drainage ditches at their confluence with the main river, creating marginal reed beds or areas of wet woodland to trap sediment at high flow. This is likely to be required where ditches are relatively deep.**	
Benefits	Constraints
• Reduction in potentially phosphorous-rich fine sediment from field drainage reaching the main river channel, improving water quality, as this could be captured and 'buffered' by wetland vegetation; • Creation of areas of marginal habitat and fish refuges where water velocity is reduced at high flow. • Reduction in rapid run off, helping to make the river more resilient to extremely low or high flow events	• Marginal reed beds or wet woodland may not be effective in every situation and further feasibility work to determine the exact details of sediment interception techniques on a site specific basis; • Occasional silt removal may be required to ensure the wetland function as effective silt traps; • Widening the lower sections of ditches may lead to a temporary release of sediment, however working methods can minimise this risk; • Widening the lower sections of tributaries will require a change in land management along the river channel (see riparian zone management); • Widening the lower sections of tributaries will require adequate space into which to widen the channel, this may be a constraint in some locations.
	

Woody Debris **Description: Woody debris is a natural feature of rivers where adjacent trees or branches fall into the channel. This provides a variety of important ecological and small-scale geomorphological functions. Woody debris (i.e. Fallen trees) should be left in place where possible instead of being removed from the river.**	
Benefits	Constraints
• Creation of in-channel sinuosity and habitat niches but unlikely to cause significant erosion in a low energy system; • Provides small-scale variations in flow velocity providing slower areas of flow and small pools that accumulate finer sediments and act as fish refuges and nursery sites, spawning habitat for bullhead; • Creates areas of cover and shading that can reduce predation of fish, but also provide foraging sites for terrestrial species such as otter; • Valuable invertebrate and algae habitats, creating food sources for fish, helping to sustain aquatic/terrestrial food chain; • Helps regulate sediment transfer and water quality by temporary trapping of mobile silts, reducing siltation of shallower gravels/riffles and turbidity; • Introduced river gravels with woody debris improves bed structure, flow variation and habitat diversity.	• Woody debris can become snagged on bridges and other structures and in exceptional events create blockages. When planning work involving the installation of woody debris, consideration should be given to the need to anchor the debris to prevent it being washed downstream and collecting on structures; • Where the river channel is relatively narrow, woody debris may accumulate in significant quantities, for example where it collects on a fallen tree, which may create an obstruction which the natural flow of the river is incapable of moving. This may increase flood risk to the surrounding land or increase the risk of bank erosion. Where such obstructions occur it may be necessary to intervene to reduce the amount of woody debris in the channel, consent for reduction or removal of woody debris; • Fallen willows, which can re-grow in the channel and lead to undesirable consequences such as excessive erosion, will require careful management.
	

Controlling Invasive Species
Description: Controlling invasive plant species such as Himalayan Balsam and Japanese Knotweed will enable native vegetation to re-establish, reducing rates of bank erosion (in the case of Himalayan Balsam) and the smothering of natural habitats. A range of methods for treating invasive species are outlined in the Environment Agency document *Guidance for the control of invasive weeds in or near fresh water.* It is important to clear upstream reaches from invasive species before downstream sections to reduce the risk of re-colonisation. Removing invasive plants will allow a more diverse assemblage of species, including protected species to colonise areas which they have previously been excluded from due to the presence and vigorous growth of these plants. Signal crayfish appear to be well established in the Wharfe so any future management should as a priority aim to prevent the spread of signals to waterbodies currently free from signals, and the protection of any nearby white clawed crayfish sites. Nationally, there is ongoing research to find an effective means of reducing signal crayfish numbers and controlling their impact. The approach on the Wharfe should be reviewed as and when new effective signal crayfish management approaches are available.

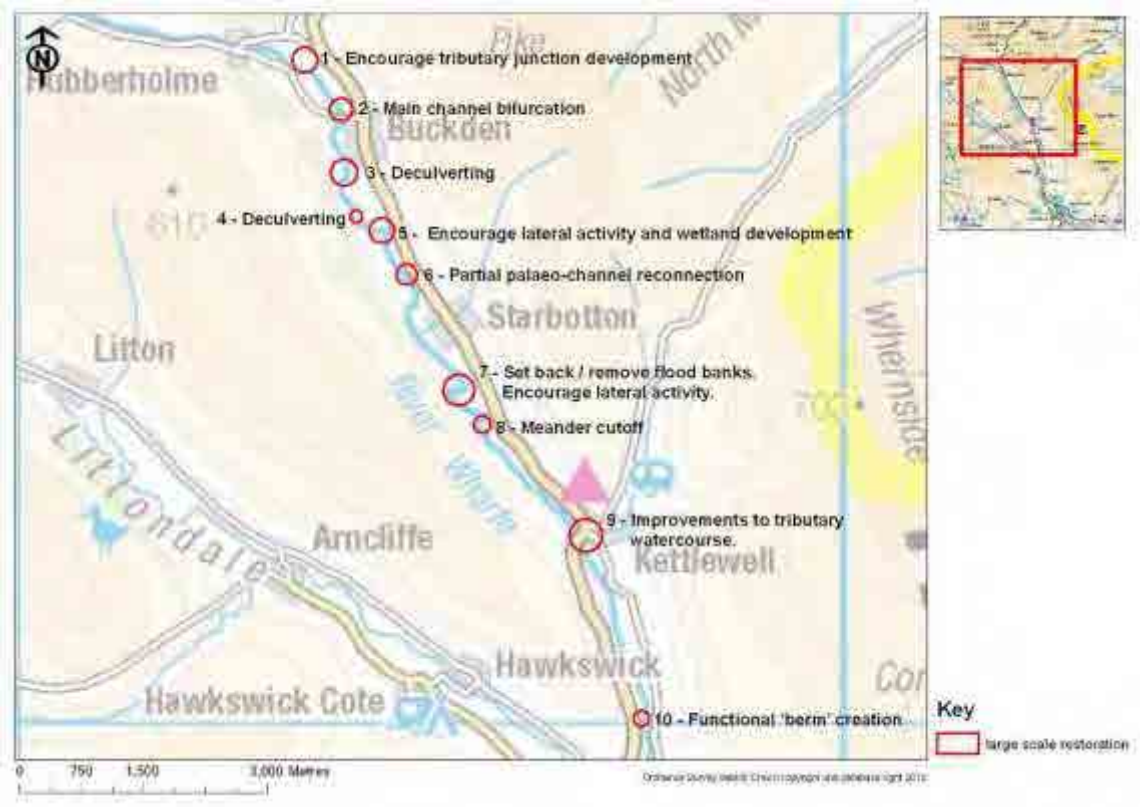
The following section sets out potential large scale (Section 5.3) and small / local scale (Section 5.4) restoration opportunities along the River Wharfe

5.3 Large scale naturalisation

The restoration potential for each reach has been categorised in to three key categories:

- Restore (existing reaches which are degraded and show no signs of naturalisation)
- Assist (Signs of naturalisation evident and where restoration activities will be least intensive)
- Rehabilitate (where the existing channel already shows some evidence of naturalisation and restoration can be used to adjust)

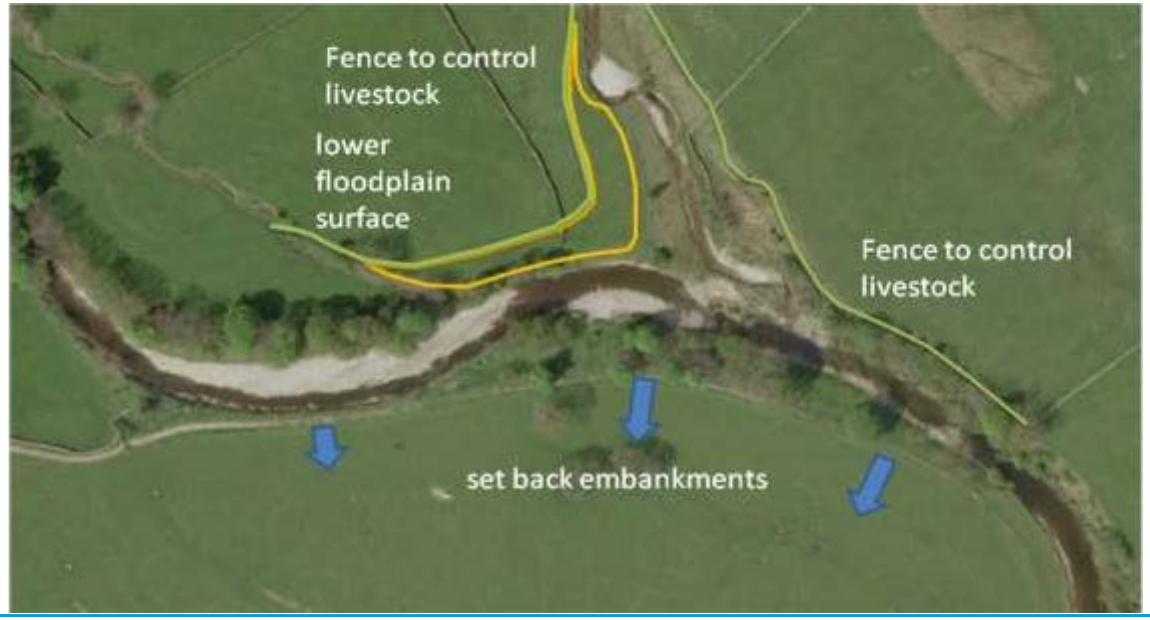
Figure 5-1 Overview of potential large scale restoration locations. Note that location 1 is outside of the SSSI but influences what happens within the site.



5.3.1 Cray Gill – Reach B1–K Wandering (OS Grid: 393475, 478001) (outside the SSSI)

Opportunity	Actions	Positive response	Considerations and constraints
Encourage tributary junction development	Limited floodplain scraping. Control stock access by managing grazing intensity by temporary or permanent fencing Set back floodbanks	Further development of well connected morphology and ecology, including several bars. Setting back embankments and increasing floodplain connectivity should promote diversity and extent of riparian habitats and associated invertebrate communities and therefore an increase in abundance of prey species Wetland habitat creation at tributary junction through increased inundation. Development of tributary junction likely to provide diverse flow regimes and in channel diversity.	Minimal release of sediment during works. This will be rapidly assimilated into the transport regime and will have minimal impact on fisheries. Minor, localised disturbance to species and habitats during works. Potential for rank, disturbance-tolerant vegetation to develop if inundation is infrequent or compaction occurs during works Braided channel and consequent reduction in channel depth may reduce accessibility to tributary for larger adult fish Some land loss in order to control livestock

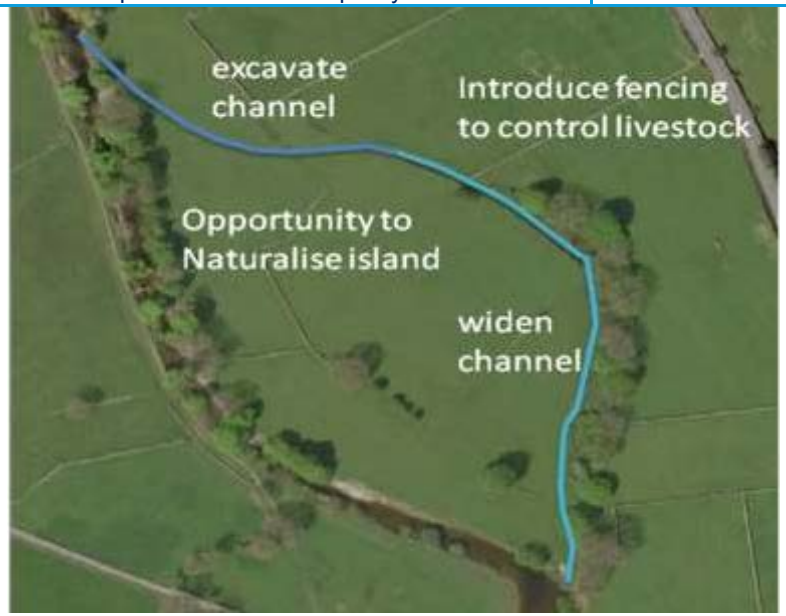
Note. This reach is not within the Wharfe SSSI



5.3.2 Upstream of Buckden Bridge – Reach B2–L Active single thread (OS Grid: 393915, 477428) (outside the SSSI)

Opportunity	Actions	Positive response	Considerations and constraints
Main channel bifurcation.	Permanent connection of the Main River Wharfe to the left bank palaeo-channel through a short excavated channel Control stock access by managing grazing intensity by temporary or permanent fencing	Creation of high flow secondary channel with associated habitats. In terms of fisheries these will be particularly valuable for juvenile life stages during normal flows. Reduced energy in main channel leading to development of gravel features and eroding banks. Increase in prevalence of gravel features in main channel likely to provide spawning opportunities, as well as providing more abundant prey species habitat. Opportunity to naturalise floodplain 'island' and introduce varied wetland, grassland and woodland habitats with consequent increase in diversity and abundance of invertebrate prey species. Creation of temporal and habitat variety across the floodplain. Improved local flood capacity.	Short term disruption to gravel transfer downstream may cause bed disruption, but unlikely to result in significant impacts, when undertaken with appropriate mitigation. Minor, localised disturbance to species and habitats during works. Some land loss in order to control livestock

Note. This reach is not within the Wharfe SSSI



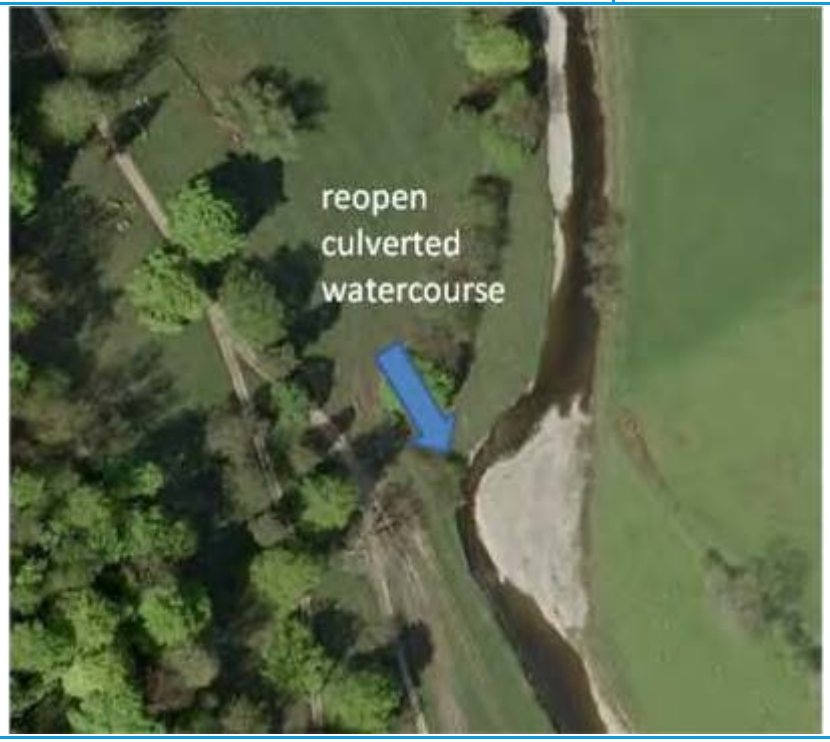
5.3.3 Southern Watergill Wood – Reach B1-O Wandering (OS Grid: 393838, 476697)

Opportunity	Actions	Positive response	Considerations and constraints
Deculverting.	Daylighting of watercourse. Potential setting back of flood defence on the left bank.	Removal of behavioural (and potential physical barrier) to lateral migration will allow exploitation of tributary by all life stages. Potential to create new in-channel and riparian habitat and will reinstate open channel habitat and will likely result in more diverse and utilisable habitat benefitting all life stages. Potential enhancement of wetland habitats (e.g. rushy pasture) upstream of culvert through increased connectivity with main river.	Minimal release of sediment during works. This will be rapidly assimilated into the transport regime and will have minimal impact on fisheries. Minor, localised disturbance to species and habitats during works.
Note. This reach is within the Wharfe SSSI			

5.3.4 Birks Wood – Reach B2-P Active single thread (OS Grid: 394066, 476118)

Opportunity	Actions	Positive response	Considerations and constraints
Deculverting.	Daylighting of watercourse	Removal of behavioural (and potential physical barrier) to lateral migration will allow exploitation of tributary by all life stages. Potential to create new in-channel and riparian habitat and will reinstate open channel habitat and will likely result in more diverse and utilisable habitat benefitting all life stages. Potential enhancement of wetland habitats (e.g. rushy pasture) upstream of culvert through increased connectivity with main river.	Minimal release of sediment during works. This will be rapidly assimilated into the transport regime and will have minimal impact on fisheries. Minor, localised disturbance to species and habitats during works.

Note. This reach is within the Wharfe SSSI



5.3.5 Eshber Wood – Reach B1-Q Wandering (OS Grid: 394399, 475933)

Opportunity	Actions	Positive response	Considerations and constraints
Set back / remove flood banks. Encourage lateral activity. Develop riparian wetland.	Allow space for the river to migrate whilst managing flooding. Control stock access by managing grazing intensity by temporary or permanent fencing	Creation of temporal and habitat variety across the floodplain. Development of wandering and later wooded anastomosed channel types likely to provide backwater habitat opportunities, particularly valuable for juvenile life stages during normal flows. Reconnection of floodplain palaeo-features. Extension and improvement of riparian wetland habitats, such as rushy pasture, wet woodland, sedge beds and meadowsweet mire. Retention of suspended fines as new floodplain deposits, increasing local extent of spawning habitats. Setting back embankments and increasing floodplain connectivity should promote diversity and extent of riparian habitats and associated invertebrate communities and therefore an increase in abundance of prey species. Development of diversity of morphological features will provide increased habitat and flow diversity exploitable by all life stages Introduction of coarse woody debris through encouragement of lateral activity.	General slow transition should preclude extreme and adverse river response. Minor, localised disturbance to species and habitats during works. Potential for rank, disturbance-tolerant vegetation to develop if inundation of palaeo-features and new habitats is infrequent or compaction occurs during works. Operational phase unlikely to result in discernible negative impacts, although careful design of features encouraging lateral activity will be necessary to ensure stranding does not occur following high flow events in the short term. Long term benefits are likely to substantially outweigh such short term impacts however. Some land loss in order to control livestock
Note. This reach is within the Wharfe SSSI			

5.3.6 Firth Wood – Reach B1-Q Wandering (OS Grid: 394695, 475374)

Opportunity	Actions	Positive response	Considerations and constraints
Partial palaeo-channel reconnection	Reconnect downstream palaeo-channel exit. Allow space for the river to migrate whilst managing flooding. Set back embankments. Control stock access by managing grazing intensity by temporary or permanent fencing	Rejuvenation of old course wetland area and creation of additional flood storage. This is likely to provide small backwater habitat opportunities, particularly refuge habitat for juvenile life stages during high flows. Increasing connections with existing palaeo-features should promote diversity and extent of wetland habitats and associated invertebrate communities and therefore an increase in abundance of prey species. Locus for fine sediment deposition Enhancement of wetland habitats within floodplain, such as rushy pasture through increased inundation. Promotion of lateral channel movement likely to give rise to increased diversity of morphological features exploitable by all life stages.	General slow transition should preclude extreme and adverse river response. Minor, localised disturbance to species and habitats during works. Fine sediment mobilisation during construction phase unlikely to result in significant impacts, when undertaken with appropriate mitigation. Some land loss in order to control livestock

Note. This reach is within the Wharfe SSSI

5.3.7 Hall Ings – Reach B1-T Wandering (OS Grid: 395335, 474059)

Opportunity	Actions	Positive response	Considerations and constraints
Set back / remove flood banks. Encourage lateral activity.	Allow space for the river to migrate whilst managing flooding. Control stock access by managing grazing intensity by temporary or permanent fencing	Creation of temporal variety across the floodplain. Development of wandering and later wooded anastomosed channel types. Setting back embankments and increasing floodplain connectivity should promote diversity and extent of riparian habitats and associated invertebrate communities and therefore an increase in abundance of prey species. Development of diversity of morphological features will provide increased habitat and flow diversity exploitable by all life stages. Creation of better connected riparian zones and enhancement of the wetland habitats within it, including rushy pasture and sedge beds. Retention of suspended fines as new floodplain deposits.	General slow transition should preclude extreme and adverse river response. Minor, localised disturbance to species and habitats during works. Operational phase unlikely to result in discernible negative impacts. Some land loss in order to control livestock

Note. This reach is within the Wharfe SSSI

5.3.8 Falcon Beard Sike – Reach B1-T Wandering (OS Grid: 395585, 473625)

Opportunity	Actions	Positive response	Considerations and constraints
Meander cutoff	Create 'chute' channel. Control stock access by managing grazing intensity by temporary or permanent fencing	High flow 'chute' will provide new periodically wet gravel habitat, and increase habitat diversity within the floodplain. Potential for creation of more 'natural' habitats on 'island' created behind chute channel. Erosion pressure on original meander bend will be much reduced. Retention of valuable deeper pool refuge and feeding station habitat, likely to be exploited by larger adult fish, on meander bend. Reduction in erosion pressure on meander bend Development of diversity of morphological features will provide increased habitat and flow diversity exploitable by all life stages.	Likely to cause longer term channel adjustment up and downstream but this mimics natural cutoff process. Minor, localised disturbance to species and habitats during works. Where geology allows, young backswamp/oxbow features seemingly already infrequent along project stretch. Prevention of maturation of this feature into such will not improve this situation. However, retention of diverse habitat promoted by this proposal will likely outweigh any limitation associated with natural development of backswamp/oxbow feature Some land loss in order to control livestock

Note. This reach is within the Wharfe SSSI

5.3.9 Kettlewell – Tributary of Reach B1-W Wandering (OS Grid: 396824, 472333)

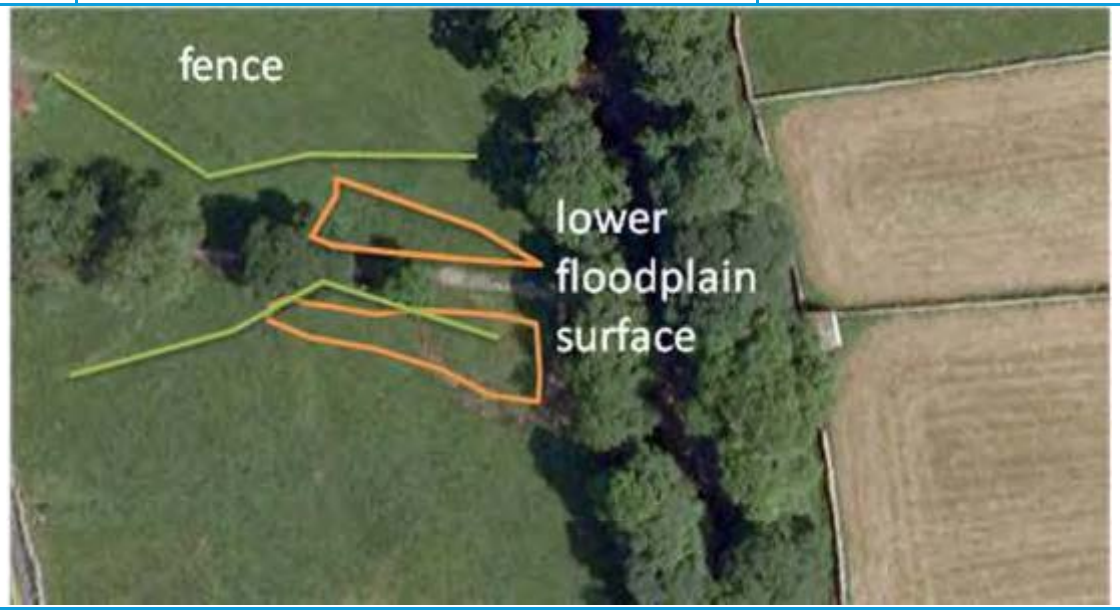
Opportunity	Actions	Positive response	Considerations and constraints
Improvements to tributary watercourse.	Removal of weir sequence.	Removal of physical barrier to lateral migration will allow exploitation of tributary by all life stages.	Minimal release of stored sediment into the main channel. This will be rapidly assimilated into the transport regime. Minor, localised disturbance to species and habitats during works, particularly fish populations. Fine sediment mobilisation during construction phase unlikely to result in significant impacts, when undertaken with appropriate mitigation. Operational phase unlikely to result in discernible negative impacts.

Note. This reach is within the Wharfe SSSI

5.3.10 Knipe Wood – Reach A1-Y Cobble step pool (OS Grid: 397778, 469280) (outside the SSSI)

Opportunity	Actions	Positive response	Considerations and constraints
Functional 'berm' creation	Excavation of limited low level lateral berm. Control stock access by managing grazing intensity by temporary or permanent fencing	Marginal habitat creation along inset reach Development of berm feature at tributary junction likely to provide diverse flow regimes and increase in-channel diversity.	Minor, localised disturbance to species and habitats during works. Fine sediment mobilisation during construction phase unlikely to result in significant impacts, when undertaken with appropriate mitigation. Operational phase unlikely to result in limited, discernible negative impacts, although braided channel and consequent reduction in channel depth may reduce accessibility to tributary for larger adult fish. Some land loss in order to control livestock

Note. This reach is not within the Wharfe SSSI



5.3.11 General large scale measures

Opportunity	Actions	Positive response	Considerations and constraints
Fine sediment control	Native tree planting along riparian zone.	Will help maintain resilience of bed gravels to fine sediment choking. Long-term reduction in fine sediment release likely to increase local extent of spawning habitats.	Operational phase unlikely to result in discernible negative impacts.
Improvements to riparian vegetation	Native tree planting along riparian zone	Reduced poaching and greater ecological diversity.	Operational phase unlikely to result in discernible negative impacts.
Management of signal crayfish, which appear to be well established in the Wharfe	Any future management should as a priority aim to prevent the spread of signals to waterbodies currently free from signals, and the protection of any nearby white clawed crayfish sites.	Reduced damage to river banks, and reduced predation on invertebrates and fish including bullhead	Nationally, there is ongoing research to find an effective means of reducing signal crayfish numbers and controlling their impact. The approach on the Wharfe should be reviewed as and when new effective signal crayfish management approaches are available.

5.3.12 Upper catchment measures

The following opportunities at a wider catchment scale will control some of the pressures discussed in Section 4.1.10.

Opportunity	Actions	Positive response	Considerations and constraints
Gill Planting and moorland drainage control	Native tree planting along riparian zone and upland valleys. De-gripping.	Will reduce flood peak magnitude and lower the frequency of extreme events reducing the ability of the river erode locally. Creation of additional woodland habitat. Reduction in magnitude of peak flow events likely to reduce washout of juvenile life stages.	Slow transition should preclude extreme and adverse river response. Operational phase unlikely to result in discernible negative impacts

5.4 Local hydromorphic improvements

Walling and other revetment is ubiquitous along the SSSI and opportunities exist to remove lengths of revetment provided long term channel movement is understood.

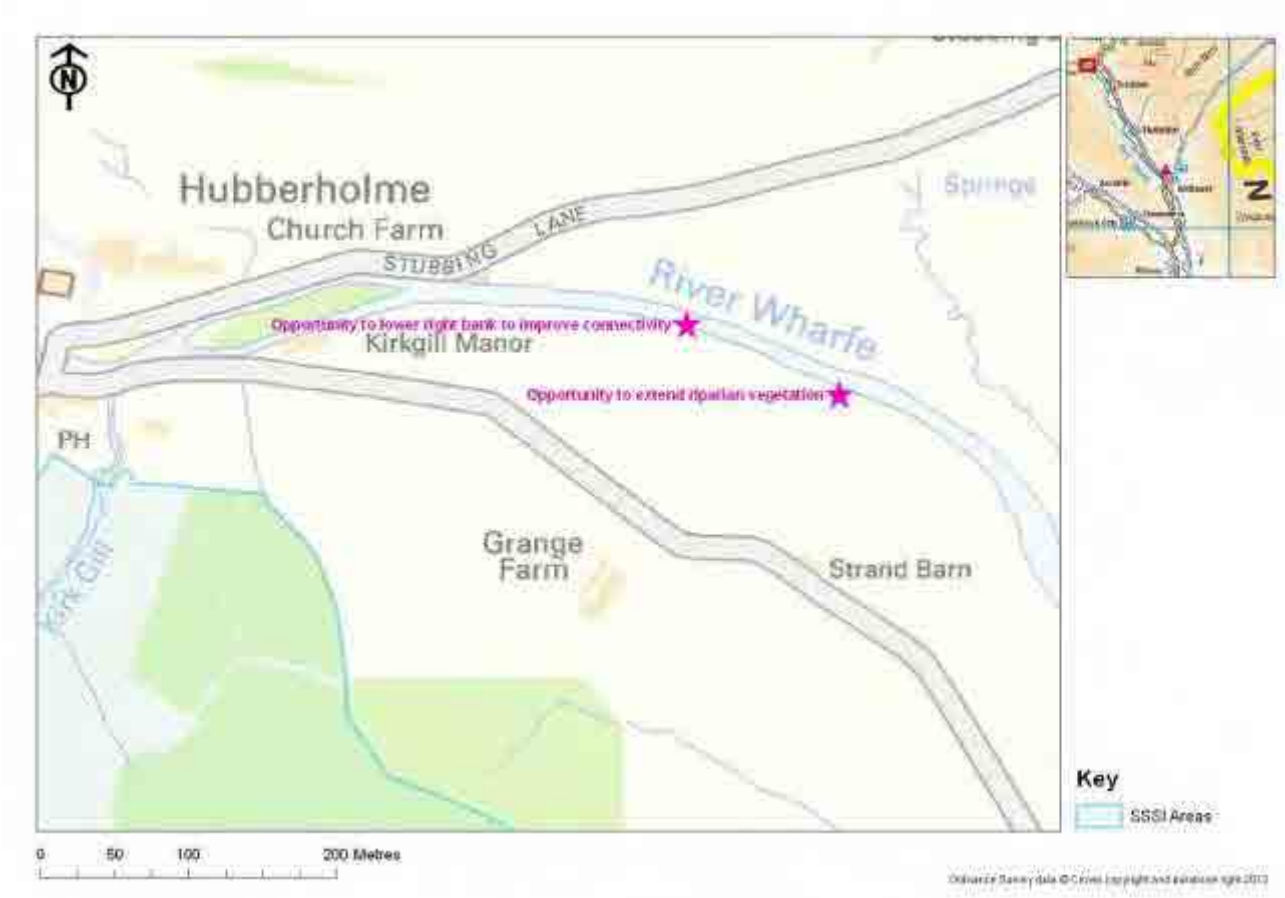
Localised improvements to riparian vegetation can also be carried out to reduce the effects of livestock poaching and also to prevent extreme lateral erosion. This should include planting with

native, locally sourced trees include willows (Crack, Grey and Willow) and Alder within the riparian corridor.

Several other local restoration opportunities exist including local in channel improvements such bar development and chute channel creation, wetland creation at tributary confluence points, de-culverting of tributaries to improve fish passage and reconnection of palaeo channels.

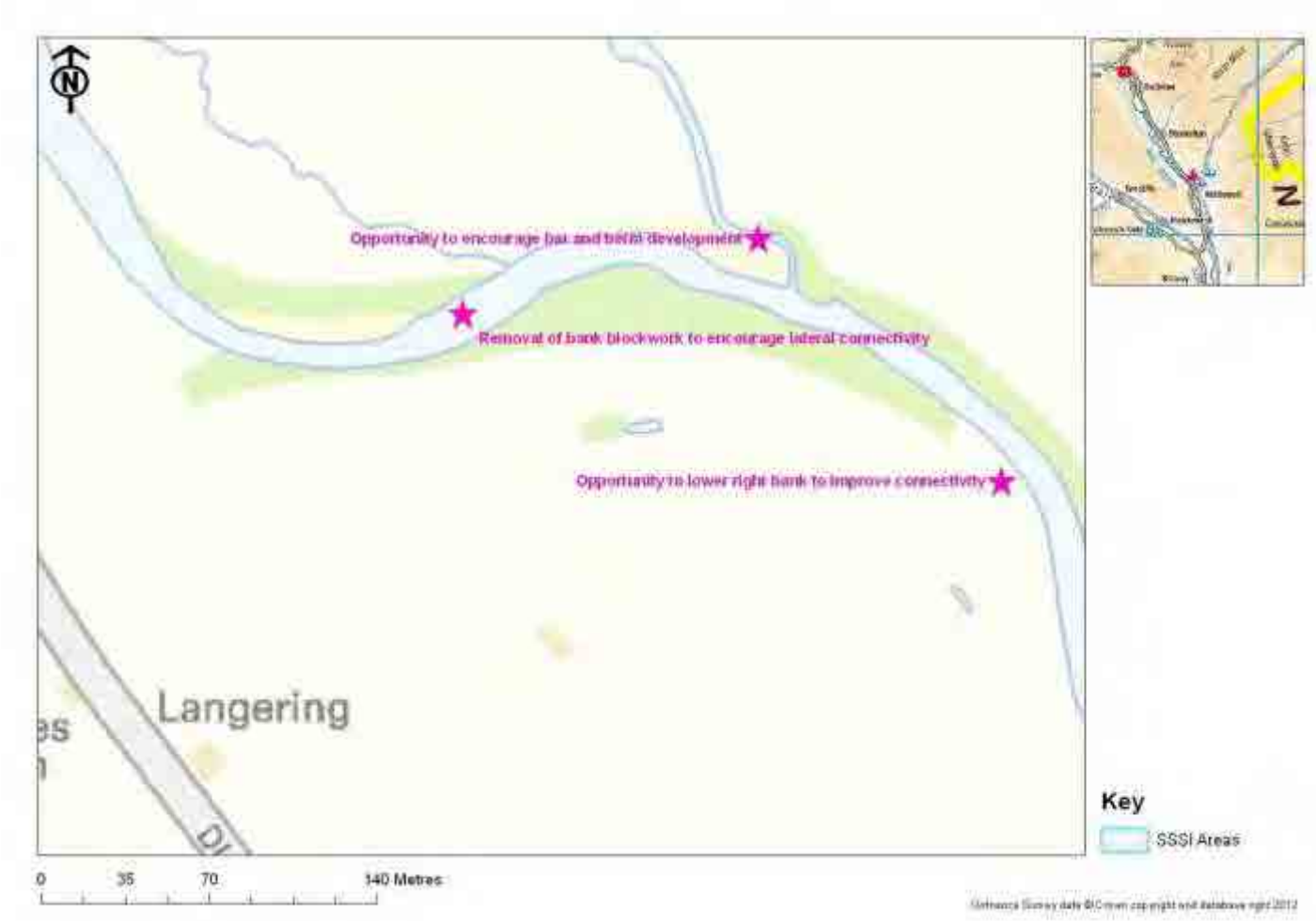
Non-native plant species control, specifically the Japanese Knotweed and Himalayan Balsam, also represents a significant opportunity to ensure that status of the SSSI is not compromised by the further spread of these invasive species.

5.4.1 Reach A1 – J (outside of the SSSI)



Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion	Lateral erosive processes will be re-instated by the removal of bank walls. Overtime this will reduce the rate of incision and begin to re-instate a natural flow regime in the channel. Removal of the existing protection will also reduce the current channel uniformity of the existing bank profile. Improvements will also be achieved for biodiversity through increasing in-channel habitat diversity and the aesthetic appearance of the channel. Long term monitoring of the erosion rate will need to be carried out. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	The removal of the existing protection and the increase of natural lateral erosion may lead some to believe that the river is out of control. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Bank side educational signs could be used to explain the processes occurring. An assessment of the historic landscape impact of traditional wall removal will be needed.
In this reach there are several localised areas where the riparian woodland is thin.	Extension of riparian woodland vegetation strip on the banks.	This could be extended to allow a zone where lateral erosion can occur freely and also protect the river banks from poaching.	Some loss of farmland will occur and there may be amenity loss for walkers and anglers as the river will be less visible.	Access point could be created for anglers through the riparian buffer zone. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.2 Reach B1 – K (outside of the SSSI)

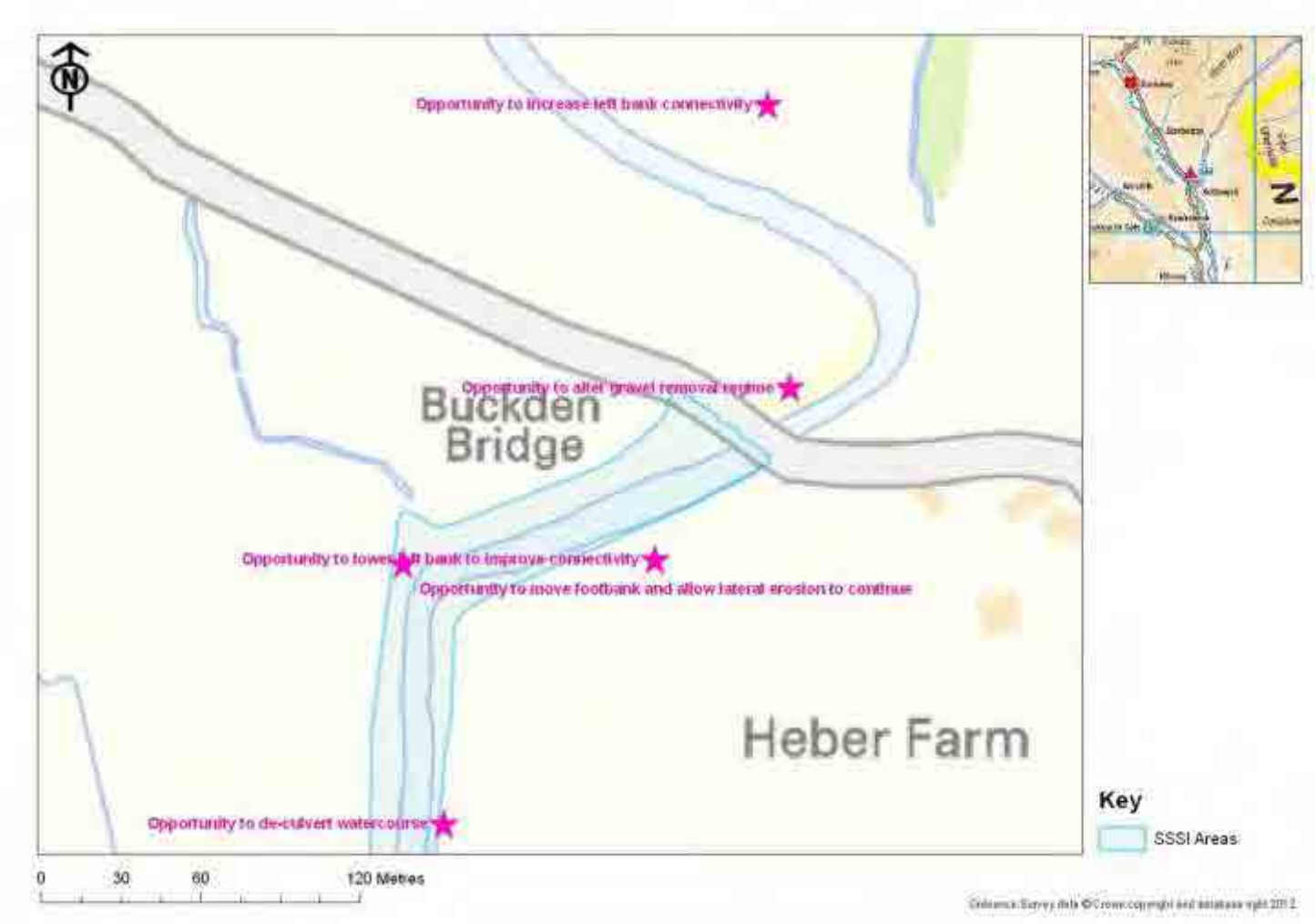


Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion. One key area within this reach is on the right bank adjacent to the old gravel trap.	Bank toe protection is frequent through this reach and this could be removed easily to encourage lateral erosion to occur and reduce the existing bank uniformity and increase in-channel habitat diversity. There is scope for the footpath to be moved. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	The footpath would be at risk of erosion as the channel naturally adjusts if not moved. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	A buffer strip could be planted to control lateral migration of the river channel if the footpath is moved. An assessment of the historic landscape impact of traditional wall removal will be needed.
The existing right bank of the river channel is 0.5m higher than the in channel water level.	Right bank floodplain reconnection by lowering the right bank (by 0.5m for up to 300m in length) to increase frequency of wetting	Improve floodplain connectivity. Wetland habitat creation.	Lowering of floodplain could mean re-routing of footpath as it would flood more frequently. Increased inundation of right bank floodplain will constrain current farming practices.	Bank side educational signs could be used to explain the processes occurring. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Poor development of in channel bars	Encourage tributary bar and berm development.	Improve in channel morphology, habitat diversity and connectivity.	Nothing significant identified	N/A

5.4.3 Reach B2 – L (outside of the SSSI)

Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion	The majority of lateral erosion as a result of removing bank protection will occur within the existing buffer strip resulting in minimal impacts on farmland Riparian woodland planting could be undertaken to provide a further buffer strip for any extreme lateral migration. New lateral erosion will reduce the current uniformity of this straight section and will help to create more diverse in channel morphology and habitat. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	Some loss of farmland due to increased erosion. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed. The footpath on the right bank could be at risk of erosion as the channel naturally adjusts.	Long term monitoring of erosion rates should be carried out. Buffer strips could be used to control extreme erosion. An assessment of the historic landscape impact of traditional wall removal will be needed. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Land in between the main river channel and the old Palaeo-channel is up to a metre higher than the water surface in some places.	Left bank floodplain reconnection by lowering bank height in between channel and palaeo-channel	Reconnection with the palaeo channel and the creation of back water areas will lead to wetland habitat creation. Improved morphology and habitat diversity within this section upstream of Buckden Bridge will also be created.	Some loss of farmland as a result of more frequent flooding	Opportunity to create a wetland area which will be beneficial to ecology on the left bank between the river and the small tributary. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

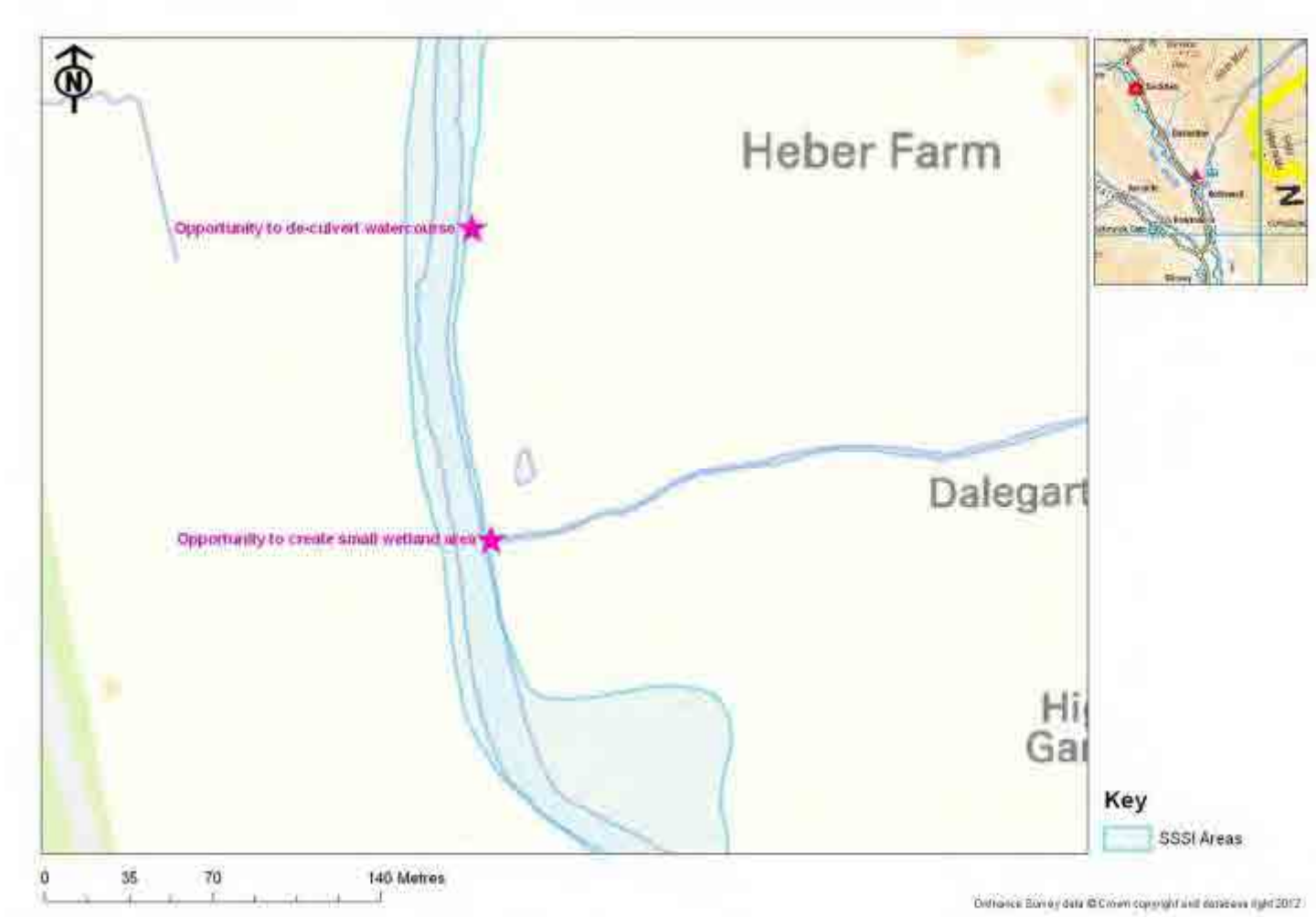
5.4.4 Reach B1 – M (inside the SSSI)



Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion (particularly left bank downstream of bridge)	A buffer strip could be used for extreme lateral erosion to protect footpath and also create additional riparian woodland planting. New lateral erosion in this section will help to create more diverse in-channel morphology and habitat and reduce uniformity. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	Footpath may have to be moved to allow for natural readjustment. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Bank side educational signs could be used to explain the processes occurring. An assessment of the historic landscape impact of traditional wall removal will be needed.
Gravel removal at Buckden Bridge which disrupts downstream continuity and sediment transport.	Currently gravel is continually removed from around the bridge. Alternative management of gravels is proposed.	Improving morphology in the reach upstream of the bridge may reduce some of the gravel build up at the bridge. Reduced disturbance to in-channel habitats and retention of gravels for fish spawning habitat.	Gravel may still build up at the bridge and cause flood risk problems	Further monitoring will be required to assess the amount of gravel accumulating at the bridge and the threat to local flood risk. EA/local land managers will then need to agree appropriate gravel management regime. In all cases it is hydromorphologically detrimental to remove gravel from the active transport system as it disrupts system morphology and transport continuity, impacts on in-channel habitats, alters the frequency and extent of natural overbank flooding and temporarily elevates fine sediment levels during removal impacting on downstream gravel integrity.
Unknown small man made diagonal weirs upstream of the bridge.	Small in channel works to improve morphology	Improve and re naturalise in channel morphology	Nothing significant identified	N/A

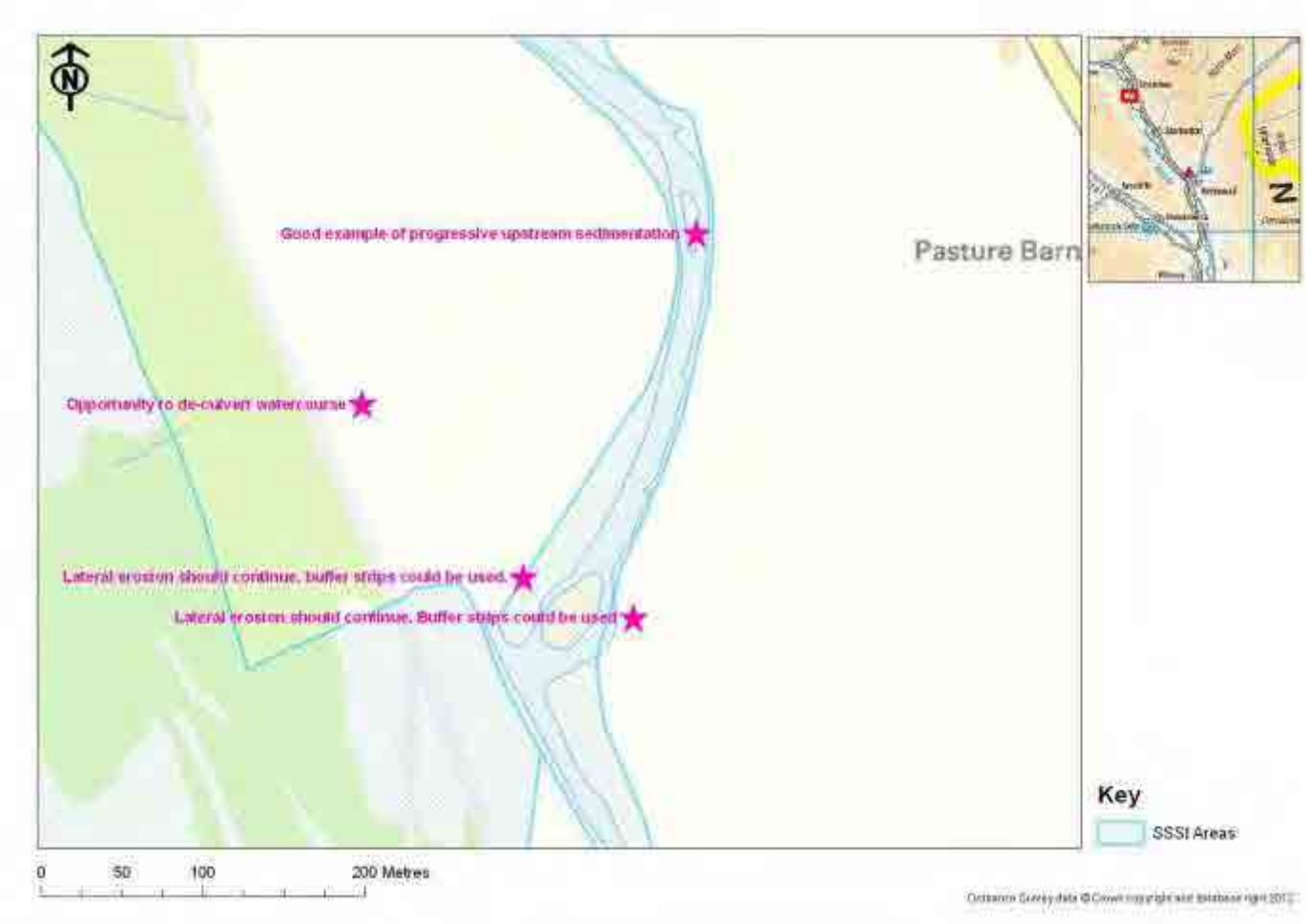
Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
High flood banks upstream of Buckden Bridge on the right bank.	Removal and / or modification of flood banks and to improve right bank floodplain connectivity downstream of Buckden Bridge	Currently flood banks restrict wetting of the right bank, although water does enter the floodplain upstream of Buckden Bridge. Removal of the floodbanks would increase floodplain connectivity and result in wetland habitat creation. A buffer strip could be used for extreme lateral erosion to protect footpath.	Increased farmland flooding. Footpath may have to be moved to allow for natural channel readjustment	The introduction of a riparian woodland buffer strip would help to limit any extreme erosion and create additional woodland habitat. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.5 Reach B2 – N (inside the SSSI)



Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion	Removal of existing toe protection and small walls will encourage lateral migration and reduce the existing simplification of the channel and increase habitat diversity. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	The removal of the existing protection and the increase of natural lateral erosion may lead some to believe that the river is out of control. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed. Footpath may have to be moved to allow for natural channel readjustment	Local educational signs adjacent to footpath educational signs could be used to explain the processes occurring. In cases of extreme lateral erosion riparian woodland buffer strips could be used. An assessment of the historic landscape impact of traditional wall removal will be needed.
High left banks restricting floodplain connectivity.	Removal and / or modification of left flood banks and to improve left bank floodplain connectivity.	Overtime this will reduce the rate of incision and begin to re-instate a natural flow regime in the channel as there will be greater floodplain interaction. Removal of the existing protection will also reduce the current channel uniformity of the existing bank profile and increase habitat diversity. Improvements will also be achieved for biodiversity, potentially through wetland habitat creation, and the aesthetic appearance of the channel.	Some loss of farmland as a result of re-profiling of banks. Potential spread of Japanese Knotweed either through capital works or increased inundation of this site.	Improved education and awareness. Japanese Knotweed control. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Poor morphology at the tributary confluence point downstream of Buckden Bridge	Creation of a small wetland area at the confluence point	Improve biodiversity	Potential spread of Japanese Knotweed either through capital works or increased inundation of this site.	Japanese Knotweed control.

5.4.6 Reach B1 – O (inside the SSSI)

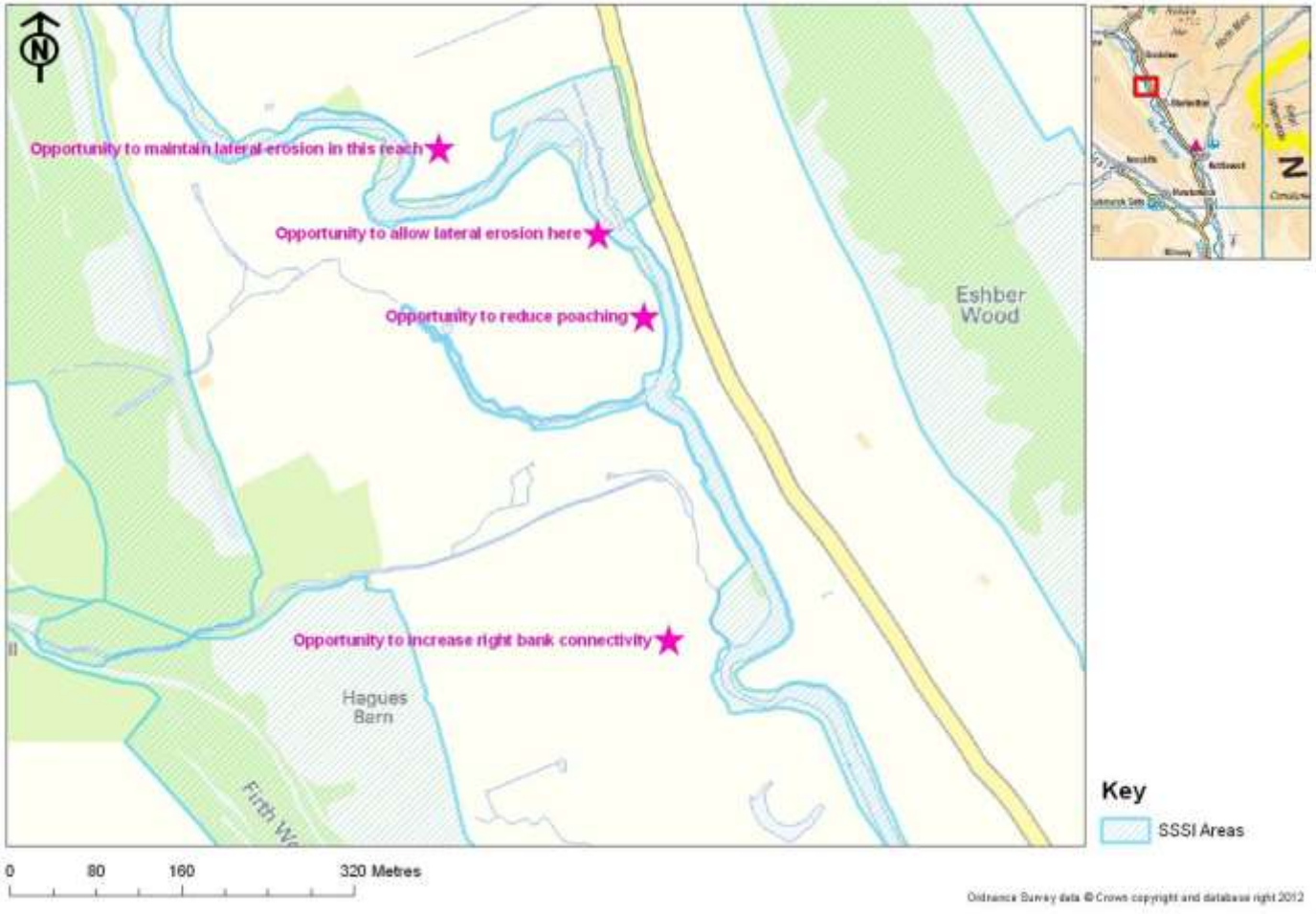


Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Existing erosion	Continue to allow lateral erosion on both left and right banks. A buffer strip could be created set back from the channel to prevent extreme lateral erosion into surrounding fields and over time introduce coarse woody debris to the river.	Significant lateral erosion is occurring in several areas within this reach providing a good gravel source. This can be managed at a reasonable rate using trees	Footpath may have to be moved to allow for natural channel readjustment	Improved education and awareness.
Limited traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion in the few places where protection exists	This will enhance the existing lateral erosion which is occurring. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	Extreme lateral erosion already occurs in this section and will be enhanced by removing any protection which exists (although existing protection is limited) Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Long term monitoring will be required to assess the extent of erosion. An assessment of the historic landscape impact of traditional wall removal will be needed.
Some floodplain disconnection on the right bank	Removal and / or modification flood banks and to improve floodplain connectivity (right bank) Deculverting of watercourse on right bank floodplain	The lowering of flood banks on the right bank will improve connectivity and allow interaction with the palaeo channel and enhance wetland habitats on the right bank floodplain. Deculverting will create additional open channel habitat and will reconnect the watercourse to the floodplain.	Footpath may have to be moved to allow for natural channel readjustment. Increased inundation of right bank floodplain will constrain current farming practices	Improved education and awareness. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.7 Reach B2 – P (inside the SSSI)

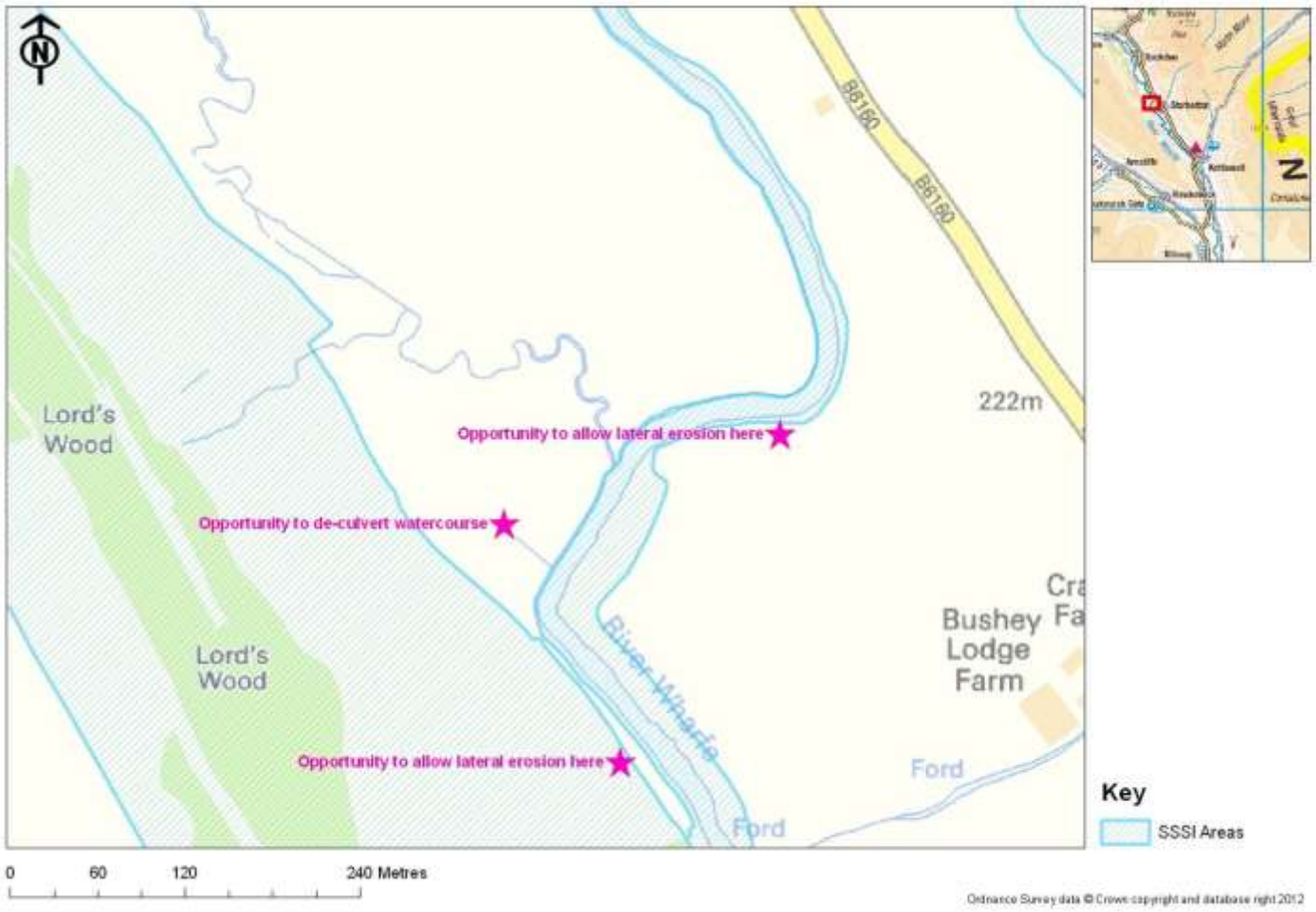
Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel. The right bank is also high and limits connectivity.	Limited bank protection and flood banks exist which has resulted in lateral erosion being frequently observed in this reach. In the few places where protection does exist it should be removed to further encourage lateral erosion. The right bank could be slightly lowered to improve connectivity.	New lateral erosion will make the channel less uniform and will help to create more diverse in-channel morphology and habitat. Improved connectivity would help create additional and enhance existing wetland areas on the right bank floodplain	Some reduction in farmland Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed. Ornamental planting may be adversely affected by increased inundation on right bank.	Further riparian woodland planting could be undertaken to provide a further buffer strip for any extreme lateral migration. An assessment of the historic landscape impact of traditional wall removal will be needed. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Short culvert is impounding tributary and impacting on fish passage.	Tributary activation through deculverting.	Improvements for fish passage. Open channel habitat will be created. Deculverting will create additional open channel habitat and will reconnect the watercourse to the floodplain.	Nothing significant identified. Some loss of farmland.	Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.8 Reach B3 – Q (inside the SSSI)



Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Erosion due to poaching	Introduce new management methods to reduce the effect of poaching	Further riparian woodland planting could be undertaken to provide a buffer strip and increased marginal vegetation in order to reduce the effects of poaching. Other livestock controls could also be used.	Some reduction in farmland and the possible release of fine sediment.	One off gravel cleaning could be undertaken downstream of poaching sites to release any trapped fine sediment. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion within this wandering section in the few places where they exist. Use soft engineering to protect road in the short term and in the long term plant blocks of suitable trees to reduce risk of erosion	Lateral erosion is already occurring in many places through this reach. Removing old bank protection and banks will allow further lateral erosion to occur. There is also an opportunity to reconnect the river to palaeo channels and back water areas within this reach to create more diverse habitats and wetland areas.	Road runs close to the channel on the left bank. Erosion is currently taking place close to road. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed. Increased inundation of floodplain will constrain current farming practices	Creation of new habitats coupled with education boards and improved awareness. An assessment of the historic landscape impact of traditional wall removal will be needed. Engineering assessment of road stability and risk. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
High banks causing poor floodplain connection.	Removal and / or modification of flood banks (in the few places where they exist) and to improve floodplain connectivity	Lateral erosion is already occurring in many places through this reach. Removing old bank protection and banks will allow further lateral erosion to occur. There is also an opportunity to reconnect the river to old palaeo channels and back water areas with this reach to create more diverse habitats and wetland areas.	Road runs close to the channel on the left bank. Erosion is currently taking place close to road	Creation of new habitats coupled with education boards and improved awareness.

5.4.9 Reach B2 – R (inside the SSSI)

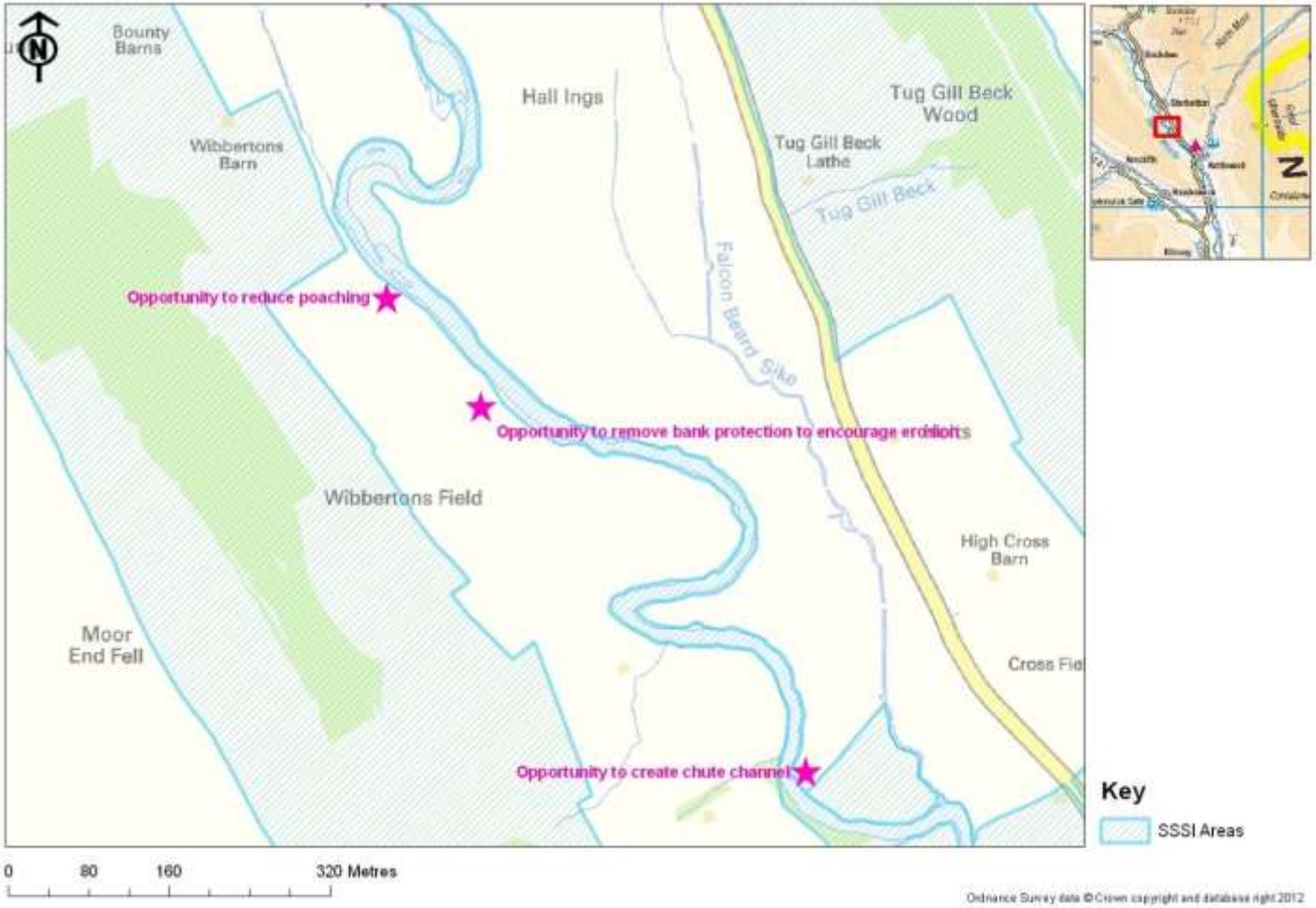


Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Tributary on left bank is partially culverted near to confluence with the Wharfe	Deculverting of this section	Open channel habitat will be created along with enhancement of existing areas and creation of new areas of wetland habitat through backflow from this channel.	Road runs close to the channel on the left bank. Erosion is currently taking place close to road. Increased inundation of floodplain will constrain current farming practices	Creation of new habitats coupled with education boards and improved awareness. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion.	Removal will increase in channel deposition and help to reduce incision within this uniform section of the river and will increase in-channel habitat diversity.	Some pockets of extreme lateral erosion may occur. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Buffer strips could be used to control extreme levels of erosion along with other soft management techniques if required. An assessment of the historic landscape impact of traditional wall removal will be needed.
Short culvert is impounding tributary and impacting on fish passage.	Tributary activation through deculverting.	Improvements for fish passage. Open channel habitat will be created.	Some loss of farmland	Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.10 Reach B4 – S (inside the SSSI)

Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
High banks (left and right) causing poor floodplain connection.	Removal and / or modification of flood banks (in the few places where they exist) and to improve floodplain connectivity.	Removal of banks would help to restore the natural flood regime and help to increase in channel morphology and habitat diversity. The existing rushy pasture area could be developed further into a diverse wetland habitat.	Some loss of farmland	Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Local removal of channel walls and toe protection to reinstate lateral erosion	Lateral erosive processes will be re-instated by the removal of bank walls. Overtime this will reduce the rate of incision and begin to re-instate a natural flow regime in the channel and increase habitat diversity. Removal of the existing protection will also reduce the current channel uniformity of the existing bank profile. Improvements will also be achieved for biodiversity and the aesthetic appearance of the channel. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	The footpath could be at greater risk of erosion. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Monitoring would need to be undertaken to assess the rate of channel adjustment. An assessment of the historic landscape impact of traditional wall removal will be needed.
Erosion due to poaching	Introduce new management methods to reduce the effect of poaching	Further riparian woodland planting could be undertaken to provide a buffer strip and increased marginal vegetation in order to reduce the effects of poaching. Other livestock controls could also be used.	Some reduction in farmland and the possible release of fine sediment.	One off sediment cleaning could be carried out to release fine sediments. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

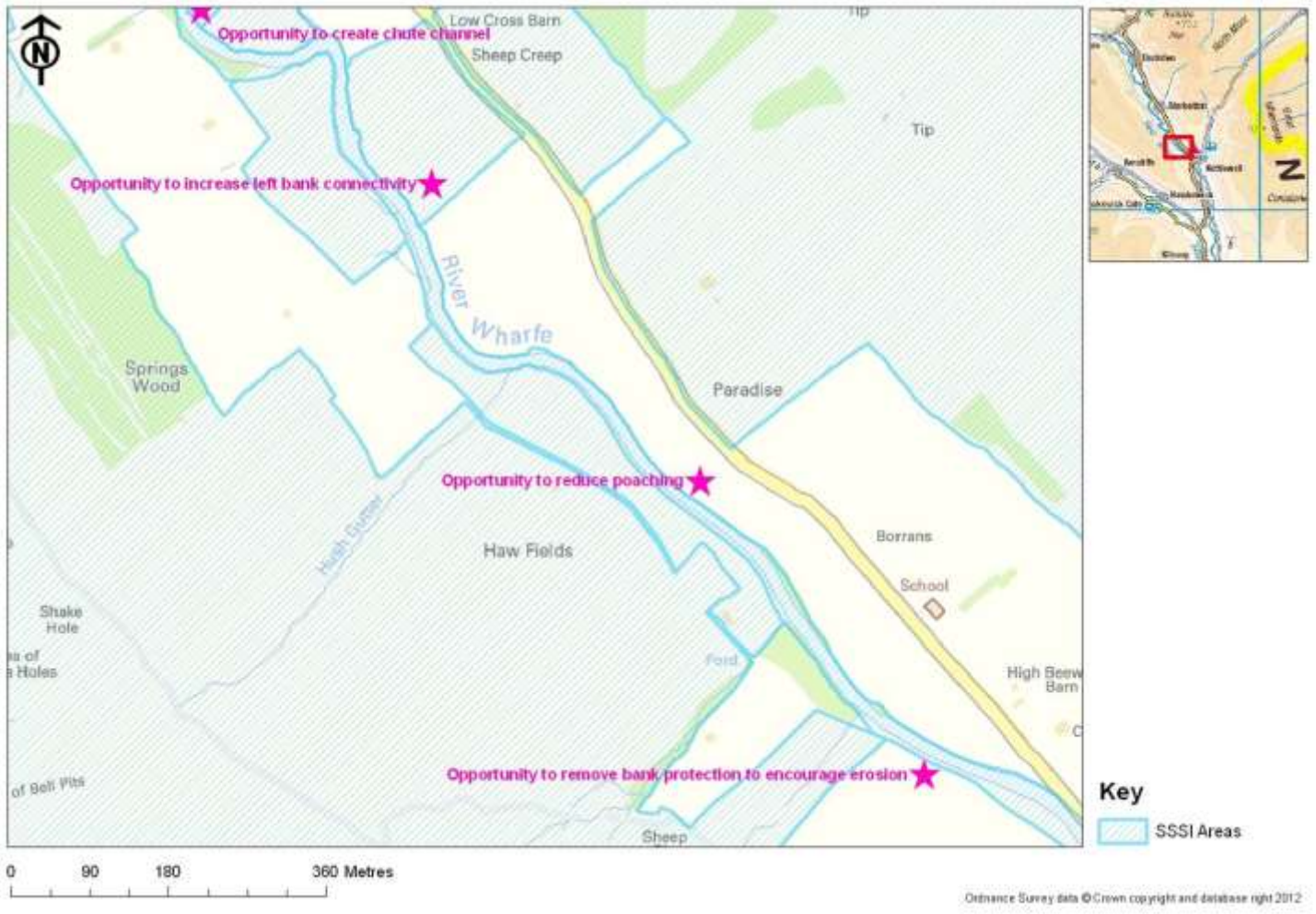
5.4.11 Reach B1 – T (inside the SSSI)



Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Poor hydromorphology at the confluence with Cray Gill Beck	Manage farm usage to control fine sediment; improve access across Cray Gill Beck. Also potential to bifurcate beck at confluence to create area of wet woodland habitat.	Improved in channel morphology and maintenance of gravel supply to the Wharfe	Nothing significant identified.	N/A.
Erosion due to poaching	Introduce new management methods to reduce the effect of poaching	Further riparian woodland planting could be undertaken to provide a buffer strip and increased marginal vegetation in order to reduce the effects of poaching.	Some reduction in farmland and the possible release of fine sediment. Some amenity loss for walkers and anglers as the river will be less visible.	One off sediment cleaning could be carried out to release fine sediments. Access could be given to anglers through the buffer strip. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Removal of bank revetment	In several locations where banks and revetment do not exist lateral erosion has taken hold. The removal of this protection will allow further erosion to take hold and will in the long term help to improve channel morphology and provide more diverse bed conditions and in channel habitats.	Some pockets of extreme lateral erosion may occur. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Monitoring would need to be undertaken to assess the rate of channel adjustment. An assessment of the historic landscape impact of traditional wall removal will be needed.

Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Address local bank erosion issues identified by Yorkshire Dales National Park Authority. Reactivate Falcon Beard Sike.	Potential to create chute channel flow diversion. Utilise palaeo-avulsion channel and isolate central floodplain area.	Improve morphology Wetland habitat creation on left bank floodplain. Reactivation of palaeo-channel between Wharfe and Falcon Beard Sike may reduce pressure on the outside of the meander near the footpath	Increased inundation of floodplain will constrain current farming practices	Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.12 Reach B2 – U (inside the SSSI)

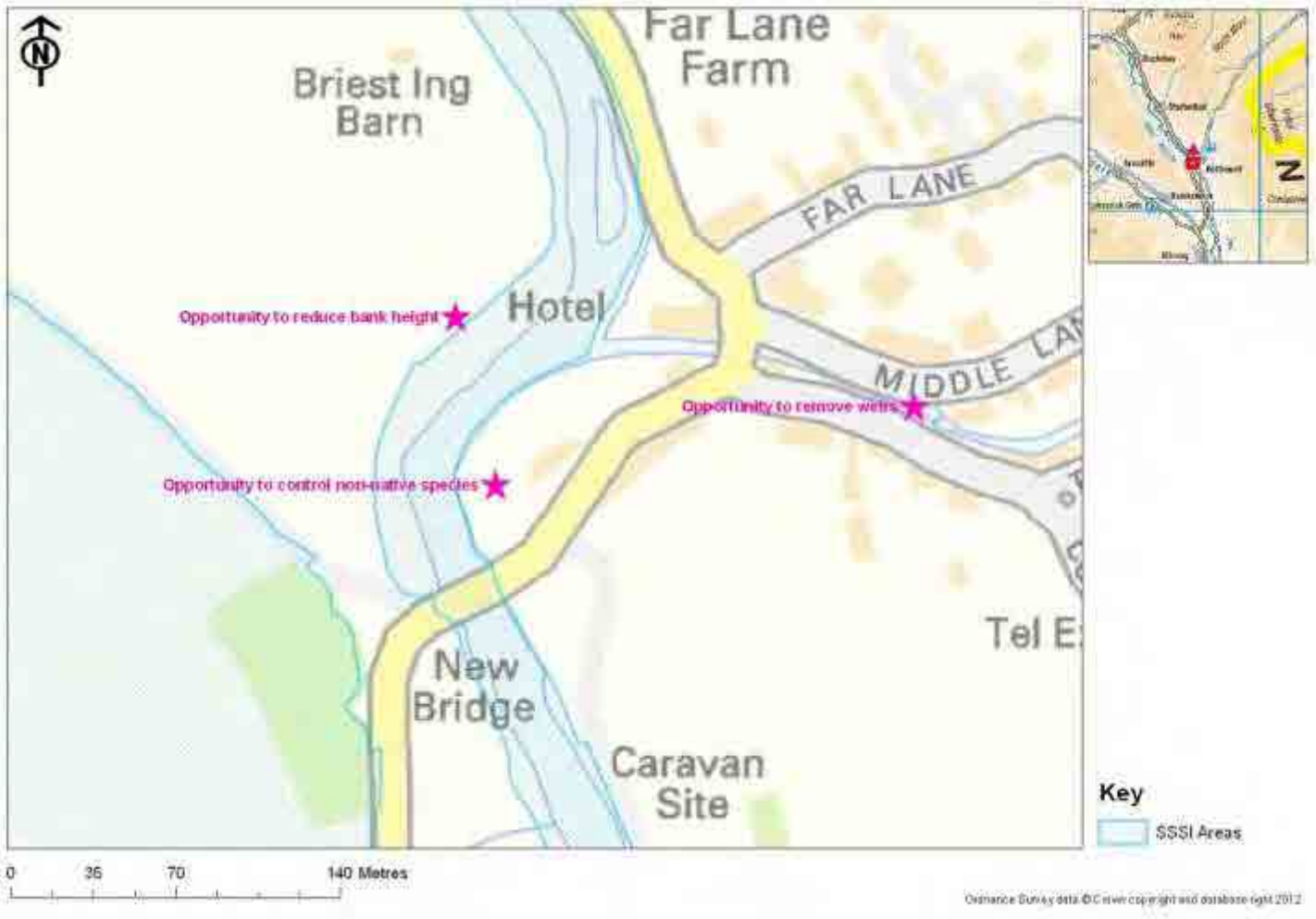


Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
High banks limiting connectivity	Removal of flood banks, especially on the left hand bank to improve floodplain connectivity.	Removal of banks would help to restore the natural flood regime and help to increase in channel morphology.	The likelihood of flooding will increase and could compromise the footpath.	Possible footpath diversion to an area less likely to flood.
Erosion due to poaching	Introduce new management methods to reduce the effect of poaching	Further riparian woodland planting could be undertaken to provide a buffer strip and increased marginal vegetation in order to reduce the effects of poaching. Other livestock controls could also be used.	Some reduction in farmland and the possible release of fine sediment.	One off sediment cleaning could be carried out to release fine sediments. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.13 Reach B4 – V (inside the SSSI)

Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Removal of flood banks, especially on the left hand bank in the upper section of this reach to improve floodplain connectivity	Much better floodplain connectivity	Increased levels of extreme erosion could occur. Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	In cases of extreme erosion soft management solutions could be introduced. An assessment of the historic landscape impact of traditional wall removal will be needed. If removal of walls threatens the road, use soft engineering techniques short term to stop it, and pre-emptively plant blocks of suitable trees to reduce risk of erosion and associated future bank protection.
High right bank limiting connectivity upstream of Kettlewell.	Improvement of right bank connectivity slightly upstream of Kettlewell by reducing bank height	Much better floodplain connectivity and possible reduction in floodlevels	Confined channel through Kettlewell so connectivity is limited	Re connecting the right floodplain upstream of Kettlewell will aid in reduction off flood levels.

5.4.14 Reach B1 – W (inside the SSSI)



Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Himalayan Balsam present on left bank upstream of Kettlewell.	Non-native species control	Eradication of Himalayan Balsam stand	N/A	N/A
Limited restoration options are available through Kettlewell due to the confined nature of the channel.	Improvements could be made on Kettlewell Beck such as weir removal any other improvements such as riparian management/shading other in channel diversity measures.	Improve in channel morphology. Improved fish passage along Kettlewell Beck.	N/A	N/A

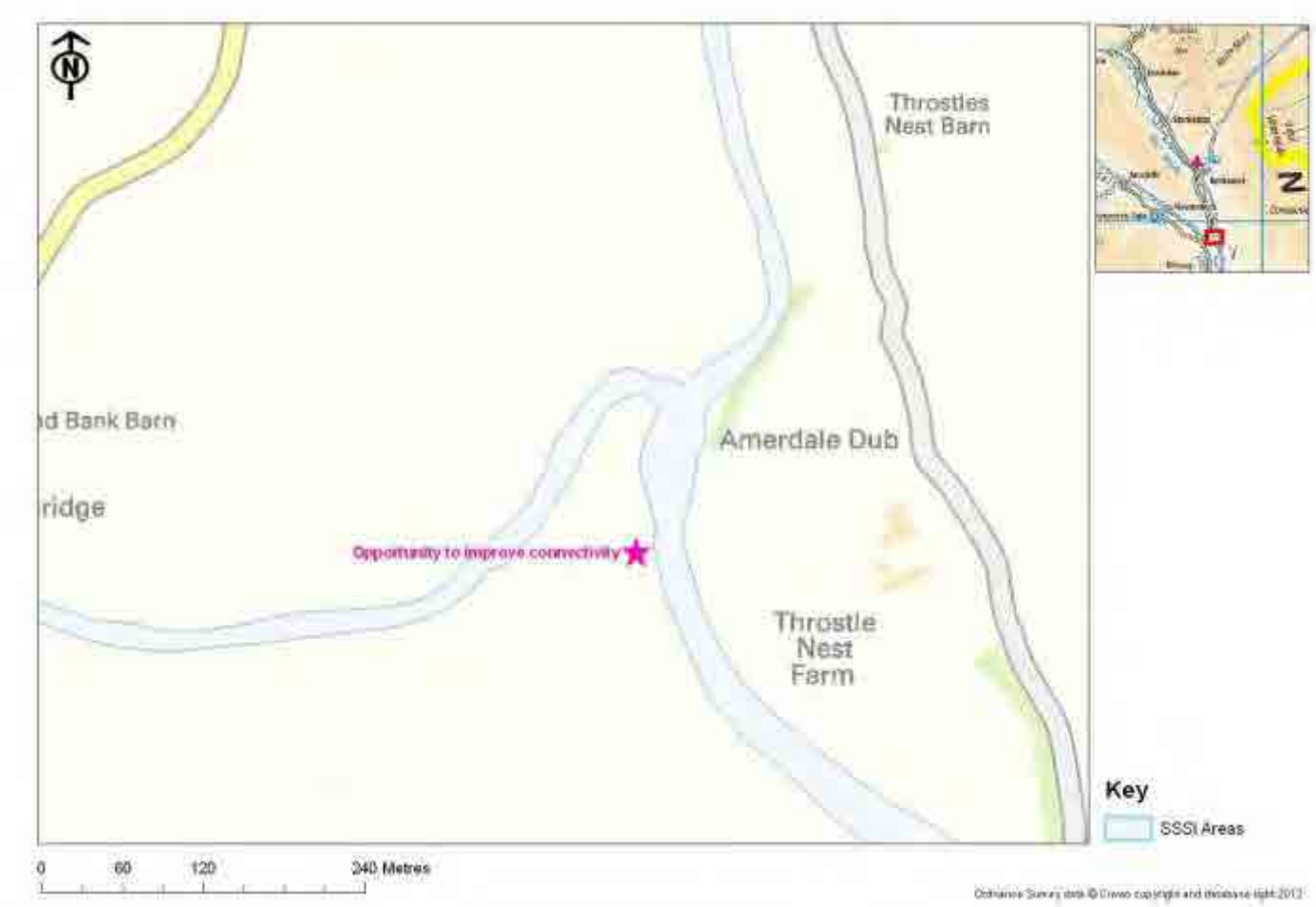
5.4.15 Reach C1 – X (inside the SSSI)

Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Removal of bank revetment	The removal of this protection will allow further erosion to take hold and will in the long term help to improve channel morphology and provide more diverse bed conditions and in channel habitats. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Improved education and awareness of why restoration work is being undertaken. An assessment of the historic landscape impact of traditional wall removal will be needed.
Erosion due to poaching	Improvements to the riparian corridor.	Introduction of a buffer zone will stop grazing at the channel edge.	Some amenity loss for walkers and anglers as the river will be less visible from the footpath.	Access point could be created into the buffer zone. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.16 Reach A2 – Y (outside of the SSSI)

Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Erosion due to poaching	Introduce new management methods to reduce the effect of poaching.	Introduction of a riparian woodland buffer zone will stop grazing at the channel edge. Other livestock controls could also be used.	Some reduction in farmland and the possible release of fine sediment.	One off sediment cleaning could be carried out to release fine sediments.
Traditional walling and bank protection along the channel edges prevents lateral erosion and creates a uniform channel.	Existing bank protection could be removed to improve lateral migration within this very uniformed and straight section	The removal of this protection will allow further erosion to take hold and will in the long term help to improve channel morphology and provide more diverse bed conditions and in channel habitats. The re-instatement of erosive processes will introduce coarse woody debris into the channel over time, again increasing in-channel habitat diversity.	Traditional walling may be an important historic landscape feature; the impact of its removal will need to be assessed.	Long term monitoring will be required to assess the extent of erosion. An assessment of the historic landscape impact of traditional wall removal will be needed. Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary

5.4.17 Reach B2 – Z (outside of the SSSI)



Existing Problem	Proposed Action	Potential Benefits	Potential negative impacts or constraints	Notes
Poor morphology	Create anastomosed channel	Reconnect with palaeo-channel at the top end of Keld Head and isolate central floodplain area leading to wetland habitat creation. Remove exotic conifers from within woodland areas on left bank of Black Keld.	Some loss of farmland	Potential change in current farming practice needs to be agreed with landowners, with appropriate support where necessary
High banks limiting floodplain connection.	Small sections of embankment in the vicinity of Lower Holme Barn could be removed to improve both left and right bank floodplain connectivity.	The removal of this protection will allow further erosion to take hold and will in the long term help to improve channel morphology and provide more diverse bed conditions and in channel habitats.	Some loss of farmland	Long term monitoring will be required to assess the extent of erosion.

6 Implementing and Delivering the Plan

This section sets out the plan for implementing the reach based solutions outlined in Section 5. These solutions will help improve the geomorphological and ecological health of the river system.

6.1 Stakeholder involvement

To achieve the aims of this river restoration plan, the Environment Agency and Natural England recognise the need for effective and positive engagement with landowners and land managers.

Landowners and land managers within 100m of the river channel and other interested parties such as angling clubs and naturalist groups were first contacted in June 2012 by letter or email explaining that the plan had been commissioned and survey work was starting that summer. Interested parties were invited to get in touch if they had any queries or concerns. Following the survey work and production of the draft plan the same individuals were sent an update in December 2012 which included an invitation to a public event in January. The update, link to the draft plan and invitation to the event was also made available on the Natural England website.

The public event was held on 15th January in Buckden, and was split into two sections. There was a 'drop-in' session in the afternoon in the village hall where representatives of JBA, the Environment Agency, Natural England, the Rivers Trust, the National Trust and the National Park were available to answer questions and talk about the plan, its background and aims. There was a poster presentation and copies of the draft could be viewed. This event was very well attended with approximately 50 to 60 people coming across the afternoon.

On the same day an evening meeting was held in the local pub. This was a more formal event, with presentations given by NE and JBA explaining the plan in further detail. It was followed by a Q&A session and further informal discussions over a free supper provided by NE. Again this was very well attended with approximately 40 people taking part. A questionnaire was available at both the daytime and evening session for people to capture their views on the Wharfe and the plan. A low number of the completed forms were returned to Natural England.

On the 16th January there were two site visits organised, one near Buckden Bridge(morning) and another in Kettlewell (afternoon). These visits focussed on two specific areas which had been highlighted in the draft plan as areas where potential restoration works could be carried out, and were lead by JBA with Natural England, the Environment Agency and the Rivers Trust also attending to answer questions. Unfortunately only a handful of people turned up but there was good discussion at each site.

During the consultation events a range of concerns were raised and acted on including:

- Listed barn at Keld Head which would restrict any reconnection at Black Keld. **Action - Due to the listed nature of the barn at this location, this proposal has been removed.**
- Tributary at Low Close Lathe. **Action - Following concerns from landowners with regards to land height at this location and the underlying bed rock this proposal has been removed.**
- Several concerns were raised with regards to animals becoming stranded on islands during high flow events. **Action - It is proposed that fences are used in areas where this is not considered a risk to livestock.**

General comments on restoration options has helped identify immovable constraints (such as major infrastructure) and additional opportunities, whilst comments on individual river reaches in this report will inform future discussions with landowners as reach specific restoration projects are taken forward.

For any of the proposals in this restoration plan to be implemented partnerships between landowners and other stakeholders will be necessary. Whilst some options will be able to be implemented over the next few years, other measures will take longer to organise with the landowners and interested parties. Some reaches will have little active intervention, but may still need agreements on adjacent land use or to allow the river to naturally recover in its own time, which may take many years.

6.2 Prioritisation of actions

It is important to prioritise actions to make the restoration plan achievable. The actions of the restoration plan have been split into two categories – short (by 2015) and long term (2050).

The following section details the priority order of restoration actions. Two sections are detailed below, the first detailing restoration actions not constrained by cost and the second detailing restoration actions constrained by cost. The costs detailed in the tables below are estimated and are based on experience from past projects. Costs will be site specific and will vary according to a number of factors including, for example, the need for further investigations, external contractors, access, reuse or disposal of materials and local gravel import.

6.2.1 Prioritising the Large Scale Restoration Actions

The large scale restoration opportunities detailed in Section 5.3 have been prioritised using several factors. For the unconstrained actions the factors used are:

- the restoration opportunity (restore, assist or rehabilitate),
- the impact (farmland loss or minor local impacts),
- the scale of the restoration (tributary based, riparian based, main channel focused, both tributary and main channel focused and whole reach works).

Each factor has been assigned a score (as detailed in the tables below). Once combined the scores have been used to rank the restoration options **(the larger score being those which should be prioritised)**.

For the constrained actions a further score has been included for cost (where -1= ~£10,0000, -2 = ~£50,000, -3 = ~£100,000, -4 = ~£200,000 and -5 = >£400,000).

6.2.2 Large Scale Restoration Actions * indicates location is outside the River Wharfe SSSI. Action is included for completeness

Short Term Actions

Location	Current Status	Restoration Opportunity	Driver and Delivery Mechanism	Hydromorph Benefits	Ecological Benefits	Impact / Constraints	Scale	Cost Banding	landowner potentially supportive	Total Uncon-strained Score (exc cost)	Total constr-ained Score (inc cost
Knipe Wood (397238, 471186)	Limited evidence of re-naturalisation	Restore (Score =1) - Lower floodplain	HLS, , , WFD - Appropriate techniques to align, diversify and attenuate flow	Improved morphology	Marginal habitat creation	Minor, localised disturbance to species and habitats during works (Score = -1)	Riparian (Score = 2)	£5,005 - £17,518 (Score = -1)	Not known	**2**	**1**
Birks Wood (394066, 476118)	No evidence of re-naturalisation	Restore (Score =1) - De-culverting of tributary and daylighting of watercourse	HLS, , WFD - Remove obsolete structures, Appropriate techniques to align, diversify and attenuate flow	Improved morphology	Will improve fish passage allowing access to upper tributary. Potential to create new in-channel and riparian habitat and will reinstate open channel habitat. Potential enhancement of wetland habitats (e.g. sedge beds) upstream of culvert through increased connectivity with main river.	Some loss of farmland. Minor, localised disturbance to species and habitats during works. (Score = -1)	Local tributary (Score = 1)	£13,415 - £46,953 (Score = -2)	Not known	**1**	**-1**
Falcon Beard Sike (395585, 473625)	No evidence of re-naturalisation	Restore (Score =1) - Meander cut off	HLS, , , WFD - - modify embankments and improve floodplain connectivity	High flow 'chute' will provide new periodically wet gravel habitat. Erosion pressure on original meander bend will be much reduced.	The chute channel will increase habitat diversity within the floodplain. Potential for creation of more 'natural' habitats on 'island' created behind chute channel.	Some loss of farmland and possible island creation in higher flows. Minor, localised disturbance to species and habitats during works. (Score = -2)	Local main channel (Score = 2)	£17,817 - £62,360 (Score = -2)	Yes	**1**	**-1**

Location	Current Status	Restoration Opportunity	Driver and Delivery Mechanism	Hydromorph Benefits	Ecological Benefits	Impact / Constraints	Scale	Cost Banding	landowner potentially supportive	Total Uncon-strained Score (exc cost)	Total constr-ained Score (inc cost
Kettlewell (396824, 472333)	No evidence of re-naturalisation	Restore (Score =1) - Remove weirs	WFD - Remove obsolete structures, Appropriate techniques to align, diversify and attenuate flow	Improved morphology, clean gravels.	Will improve fish passage allowing access to upper tributary.	Minimal release of stored sediment into the main channel and some localised geomorphic instability. This will be rapidly assimilated into the transport regime. (Score = -1) Minor, localised disturbance to species and habitats during works, particularly fish populations.	Local tributary (Score = 1)	£56,600 - £198,100 (Score = -3)	Yes	**1**	**-2**
Southern Watergill Wood (393838, 476697)	No evidence of re-naturalisation	Restore (Score =1) - De-culverting of tributary and daylighting of watercourse	HLS, , WFD - Remove obsolete structures, Appropriate techniques to align, diversify and attenuate flow	Improved morphology	Will improve fish passage allowing access to upper tributary. Potential to create new in-channel and riparian habitat and will reinstate open channel habitat. Potential enhancement of wetland habitats (e.g. rushy pasture) upstream of culvert through increased connectivity with main river.	Some loss of farmland. Minor, localised disturbance to species and habitats during works. (Score = -2)	Local tributary (Score = 1)	£63,815 - £223,353 (Score = -3)	Not known	**0**	**-3**

Long Term Actions * indicates location is outside the River Wharfe SSSI. Action is included for completeness

Location	Current Status	Restoration Opportunity	Driver and Delivery Mechanism	Hydromorph Benefits	Ecol Benefits	Impact / Constraints	Scale	Cost Banding	landowner potentially supportive	Total Unconstrained Score (exc cost)	Total constrained Score (inc cost
Hall Ings (395335, 474059)	Limited evidence of re-naturalisation	Assist (Score =3) - Set back / remove flood banks. Encourage lateral activity.	HLS, , , WFD	Development of wandering and later wooded anastomosed channel types. Reconnection of floodplain palaeo-features. Retention of suspended fines as new floodplain deposits.	Creation of temporal variety across the floodplain. Creation of better connected riparian zones and enhancement of the wetland habitats within it, including rushy pasture and sedge beds. Introduction of coarse woody debris through encouragement of lateral activity	Some loss of farmland. Minor, localised disturbance to species and habitats during works. (Score = -2)	Reach (Score = 4)	£90,770 - £317,695 (Score = -4)	Yes	**5**	**1**
Eshber Wood (394399, 475933)	Limited evidence of re-naturalisation	Rehabilitate (Score =2) - Set back / remove flood banks. Encourage lateral activity. Develop riparian wetland.	HLS, , , WFD - modify embankments and improve floodplain connectivity	Development of wandering and later wooded anastomosed channel types. Reconnection of floodplain palaeo-features. Retention of suspended fines as new floodplain deposits	Creation of temporal and habitat variety across the floodplain. Extension and improvement of riparian wetland habitats, such as rushy pasture, wet woodland, sedge beds and meadowsweet mire. Introduction of coarse woody debris through encouragement of lateral activity	Some loss of farmland. Minor, localised disturbance to species and habitats during works. (Score = -2) Potential for rank, disturbance-tolerant vegetation to develop if inundation of palaeo-features and new habitats is infrequent or compaction occurs during works.	Reach (Score = 4)	£169,430 - £593,005 (Score = -5)	Not known	**4**	**-1**
Firth Wood (394695, 475374)	Limited evidence of re-naturalisation	Restore (Score =1) - Partial palaeochannel reconnection	HLS, , WFD - improve floodplain connectivity, Appropriate techniques to align,	Rejuvenation of old course wetland area and creation of additional	Enhancement of wetland habitats within floodplain, such as rushy pasture through increased inundation.	Some loss of farmland. Minor, localised disturbance to species and habitats	Reach (Score = 4)	£45,410 - £158,935 (Score = -3)	Not known	**3**	**0**

Location	Current Status	Restoration Opportunity	Driver and Delivery Mechanism	Hydromorph Benefits	Ecol Benefits	Impact / Constraints	Scale	Cost Banding	landowner potentially supportive	Total Unconstrained Score (exc cost)	Total constrained Score (inc cost
			diversify and attenuate flow	flood storage Locus for fine sediment deposition		during works. (Score = -2)					
*Upstream of Buckden Bridge (93915, 477428)	No evidence of re-naturalisation	Restore (Score =1) - Main channel bifurcation - following line of old palaeo channel	HLS, , , WFD - modify embankments and improve floodplain connectivity	Creation of high flow secondary channel Reduced energy in main channel leading to development of gravel features and eroding banks. Opportunity to naturalise floodplain 'island'.	New habitats in secondary channel. Opportunity to naturalise island and introduce varied wetland, grassland and woodland habitats. Creation of temporal and habitat variety across the floodplain. Improved local flood capacity.	Some loss of farmland, island creation in higher flows. Minor, localised disturbance to species and habitats during works. (Score = -2)	Reach (Score = 4)	£189,077 - £661,770 (Score = -5)	Not known	**3**	**-2**
*Cray Gill (393475, 478001)	Limited evidence of re-naturalisation	Restore (Score =1) - Encourage tributary junction development by lowering floodplain and setting back embankments	HLS, , , WFD - modify embankments and improve floodplain connectivity	Improved in channel morphology	Wetland habitat creation at tributary junction through increased inundation	Some loss of farmland. Minor, localised disturbance to species and habitats during works. Potential for rank, disturbance-tolerant vegetation to develop if inundation is infrequent or compaction occurs during works. (Score = -2)	Local main channel & tributary (Score = 3)	£80,574 - £282,009 (Score = -4)	Not known	**2**	**-2**

6.2.3 Localised Restoration Actions

The localised restoration actions outlined in Section 5.4 such as removing channel training and combating invasive species could provide quick win solutions. Several of the actions detailed in Section 5.4 will complement and can / should be actioned alongside the large scale actions detailed in Section 5.3. Table 6-1 gives an overview of indicative restoration costs for the proposed local restoration actions. This does not include costs such as site supervision or costs such as mobilisation and demobilisation which could add up to 40% to the overall cost.

Table 6-1. Local restoration costs which must be considered * indicates location is outside the the River Wharfe SSSI. Action is included for completeness

Reach	Proposed Action	Link to large scale restoration	Distance (m)	Upper Band Cost	Lower Band Cost	Rank by total reach cost
*A1 – J	Local removal of channel walls and toe protection to reinstate lateral erosion		400	£28,000.00	£8,000.00	4
	Extension of riparian woodland vegetation strip on the banks.		400	£70,000.00	£20,000.00	
*B1 – K	Local removal of channel walls and toe protection to reinstate lateral erosion. One key area within this reach is on the right bank adjacent to the old gravel trap.	In conjunction with the larger restoration proposal at Cray Gill	250	£17,500.00	£5,000.00	9
	Right bank floodplain reconnection by lowering the right bank (by 0.5m for up to 300m in length) to increase frequency of wetting		300	£168,000.00	£48,000.00	
*B2 – L	Local removal of channel walls and toe protection to reinstate lateral erosion	In conjunction with the larger restoration proposal upstream of Buckden Bridge	400	£28,000.00	£8,000.00	2
*B1 – M	Local removal of channel walls and toe protection to reinstate lateral erosion (particularly left bank downstream of bridge)		100	£7,000.00	£2,000.00	6
	Currently gravel is continually removed from around the bridge. Alternative management of gravels is proposed.		100	£42,000.00	£12,000.00	
	Small in channel works to improve morphology		100	£42,000.00	£12,000.00	
	Removal and / or modification of flood banks and to improve right bank floodplain connectivity downstream of Buckden Bridge		100	£42,000.00	£12,000.00	
B2 – N	Local removal of channel walls and toe protection to reinstate lateral erosion		25	£1,750.00	£500.00	3
	Removal and / or modification of left flood banks and to improve left bank floodplain connectivity.		25	£14,000.00	£4,000.00	
	Creation of a small wetland area at the confluence point		30	£12,600.00	£3,600.00	

Reach	Proposed Action	Link to large scale restoration	Distance (m)	Upper Band Cost	Lower Band Cost	Rank by total reach cost
B1 – O	Continue to allow lateral erosion on both left and right banks. A buffer strip could be created set back from the channel to prevent extreme lateral erosion into surrounding fields and over time introduce coarse woody debris to the river.	Alongside the larger restoration proposal at Southern Water gill Wood (De culverting)	300	£168,000.00	£48,000.00	13
	Local removal of channel walls and toe protection to reinstate lateral erosion in the few places where protection exists		300	£21,000.00	£6,000.00	
	Removal and / or modification flood banks and to improve floodplain connectivity (right bank)		300	£168,000.00	£48,000.00	
B2 – P	Limited bank protection and flood banks exist which has resulted in lateral erosion being frequently observed in this reach. In the few places where protection does exist it should be removed to further encourage lateral erosion. The right bank could be slightly lowered to improve connectivity.	Alongside the larger restoration proposal at Birks Wood (De culverting)	230	£128,800.00	£36,800.00	5
B3 – Q	Introduce new management methods to reduce the effect of poaching	In conjunction with the larger restoration proposals at Firth Wood and Eshber Wood	1000	£11,200.00	£3,200.00	17
	Local removal of channel walls and toe protection to reinstate lateral erosion within this wandering section in the few places where they exist. Use soft engineering to protect road in the short term and in the long term plant blocks of suitable trees to reduce risk of erosion		1000	£70,000.00	£20,000.00	
	Removal and / or modification of flood banks (in the few places where they exist) and to improve floodplain connectivity		1000	£560,000.00	£160,000.00	
B2 – R	Deculverting of this section		200	£112,000.00	£32,000.00	16
	Local removal of channel walls and toe protection to reinstate lateral erosion.		800	£56,000.00	£16,000.00	
	Tributary activation through deculverting.		800	£448,000.00	£128,000.00	
B4 - S	Removal and / or modification of flood banks (in the few places where they exist) and to improve floodplain connectivity.		650	£364,000.00	£104,000.00	14
	Local removal of channel walls and toe protection to reinstate lateral erosion		650	£45,500.00	£13,000.00	
	Introduce new management methods to reduce the effect of poaching		650	£7,280.00	£2,080.00	
B1 – T	Manage farm usage to control fine sediment; improve access across Cray Gill Beck. Also potential to bifurcate beck at confluence to create area of wet woodland habitat.	In conjunction with larger restoration proposals at Halls Ings and Falcon Beard Syke	1500	£16,800.00	£4,800.00	7
	Introduce new management methods to reduce the effect of poaching		1500	£16,800.00	£4,800.00	

Reach	Proposed Action	Link to large scale restoration	Distance (m)	Upper Band Cost	Lower Band Cost	Rank by total reach cost
	Removal of bank revetment		1500	£105,000.00	£30,000.00	
B2 – U	Removal of flood banks, especially on the left hand bank to improve floodplain connectivity.		1000	£560,000.00	£160,000.00	15
	Introduce new management methods to reduce the effect of poaching		1000	£11,200.00	£3,200.00	
B4 – V	Removal of flood banks, especially on the left hand bank in the upper section of this reach to improve floodplain connectivity		200	£112,000.00	£32,000.00	10
	Improvement of right bank connectivity slightly upstream of Kettlewell by reducing bank height		200	£112,000.00	£32,000.00	
B1 – W	Non-native species control	Alongside the larger restoration proposals at Kettlewell weir	300	£8,400.00	£2,400.00	1
C1 – X	Removal of bank revetment		1200	£84,000.00	£24,000.00	12
	Improvements to the riparian corridor.		1200	£252,000.00	£72,000.00	
*A2 – Y	Introduce new management methods to reduce the effect of poaching.		1800	£20,160.00	£5,760.00	8
	Existing bank protection could be removed to improve lateral migration within this very uniformed and straight section		1800	£126,000.00	£36,000.00	
*B2 – Z	Create anastomosed channel		300	£126,000.00	£36,000.00	11
	Small sections of embankment in the vicinity of Lower Holme Barn could be removed to improve both left and right bank floodplain connectivity.		300	£168,000.00	£48,000.00	

Note: any potential changes in land use and floodplain connectivity would need to be agreed with landowners, with appropriate support in place e.g Environmental Stewardship.

In a number of locations there is a need for modifications to remain to protect where people, infrastructure and buildings from flood risk and excessive erosion.

6.3 Delivery mechanisms and Funding Sources

The river restoration plan is based on partnership working, long time scales suited to the nature and scale of each site's problems and solutions, negotiating solutions, and a best endeavours approach to implementation. There is no one source of funding available to deliver river restoration, and funds will need to be sought to deliver and maintain implementation of the plan over time, including bids to budgets such as EA Flood and Coastal Risk Management (FCRM) capital works, Catchment Restoration Funds (CRF) but also opportunistic bids to a range of other funding sources including European programmes. Work in-kind from other organisations, including partners such as the Rivers Trusts and angling clubs has a vital part to play.

6.3.1 Rivers Trusts

The Yorkshire Dales Rivers Trust is an environmental charity established to promote the preservation, protection and improvement of the rivers and streams. Rivers Trusts are a cost-effective means of delivering environmental, social and economic outputs with strong community stakeholder involvement.

6.3.2 European Funding

The LIFE programme is the EU's funding mechanism for the environmental improvement initiatives. LIFE projects support a wide range of water-related issues, such as urban water management, industrial wastewater treatment, river basin monitoring and improving groundwater quality. LIFE has co-financed over 3000 projects across the EU, equating to approximately €2.2bn to the protection of the environment.

6.3.3 Environmental Stewardship Schemes

The Environmental Stewardship scheme is an appropriate source of funding for this type of work, and is particularly appropriate to measures aimed at improving the riparian zone and giving the river more space by defining such land as buffer strips. Improvements to the riparian zone can also provide improved soil conservation, especially in arable areas.

There are a number of levels of Stewardship:

- Entry Level Stewardship;
- Organic Entry Level Stewardship;
- Upland Entry Level Stewardship; and
- Higher Level Stewardship.

The Higher Level Stewardship (HLS) provides funding for land management / land use changes relating to proposals such as livestock management and improved wetland riparian land use (Natural England encourage enhancements of at least 12m width buffer strips for watercourses on cultivated land).

The current Rural Development Programme ends in December 2013 and the new programme is expected to start from January 2015 onwards. In between the end of the current programme and the start of the next one, more than 13,000 ELS, 400 Organic ELS, 1300 Countryside Stewardship and 1,400 ESA agreements will expire. Defra are actively discussing with the European Commission what can be done in this interim period to allow a smooth transition to the new programme.

6.3.4 Catchment Sensitive Farming

Catchment Sensitive Farming is a partnership between the Environment Agency and Natural England, funded by DEFRA and the EU Rural Development Programme. The initiative delivers practical solutions to reduce diffuse pollution from agricultural land to protect water bodies and habitats. Funding is prioritised and targeted within each catchment through a Funding Priority Statement.

6.3.5 Catchment Restoration Fund

The Department for Environment, Food and Rural Affairs (Defra) has created the Catchment Restoration Fund to support this aim. This is a £28m fund, providing up to £10m each year, has been allocated for projects to be delivered in 2012/13, 2013/14 and 2014/15. **However, due to increased financial pressures the fund will no longer be running in 2013.**

6.3.6 MORE woods

MORE woods is a UK wide scheme run by the Woodland Trust. It supports people who aren't receiving government grants to plant woods, shelterbelts and windbreaks. If you have one hectare of land or more for planting, the Woodland Trust can guide you from start to finish and beyond, providing:

- onsite advice discussing the design and species appropriate for your site
- financial support to help you plant
- an expert advisory service after you've planted to ensure your new wood flourishes.

6.3.7 English Woodland Grant Scheme

A suite of grants that are available for the management and planting of woodland. Some are target based for specific important and rare species or important areas (e.g. Sites of Special Scientific Interest) and others are more genera. Details of the EWGS can be found on the Forestry Commission England website.

6.4 Implementation

The plan is a long term strategy and whilst some options will be able to be implemented quickly others will take longer to develop through further partnership working. Each restoration measure will require further more detailed costing and site investigation before any measure is implemented, including detailed flood risk assessments.

The plan will be freely available to all and can be accessed from either the Environment Agency or Natural England websites. Printed copies can be made available on request. Progress on the plan will be reported on through delivery processes against funding and where possible more widely. The plan shows the options that have been identified as desirable to meet the conservation objectives for each river reach and the overall ecological vision for the river. These options will need to be developed in the future through detailed consultation with key stakeholders (including landowners, land managers, riparian users, conservation bodies and recreational groups).

It should be noted that the proposed river restoration options for the nature conservation management of the River Wharfe SSSI may have negative effects on the site features or adjacent sites if not designed appropriately, taking into all account all the interest features of the site, or if carried out in the wrong place within a site, or at the wrong time of year. As detailed implementation projects are developed from the Plan and before they can be undertaken or permitted, they are subject to further controls as follows:

All implementation projects will either require permissions from the Environment Agency and/or Natural England. As part of these procedures and where relevant Habitats Regulations Assessment of individual projects as submitted will be required to ensure that they do not have significant negative effects on any European sites either alone or in combination with other plans and projects. This is particularly applies to potential restoration actions in the vicinity of Hubberholme.

Over the summer of 2013 the Rivers Trust and the National Trust began talking to land managers and started to develop plans for river restoration works. These included fencing of a large section of the river bank from Buckden south and planting it up, removing a small section of flood bank and potentially opening up a culvert. These plans are now being finalised with input from the Environment Agency and Natural England with a view to implementation this winter.

In November 2013 another update was sent to the landowners/interested parties as well as an invitation to visit the River Ribble at Long Preston Deeps where a River Restoration Plan is already being implemented. The visit took place on 15th November and a free mini-bus to and from the site from Buckden was provided, as well as lunch. There were short presentations by Natural England, the Rivers Trust and the Environment Agency before a meeting with local farmers on site who had had works such as setting back of flood banks and chute channels carried out. Although there was a low turnout of Wharfe farmers, those who attended found it very useful to speak to the Ribble farmers about the experience.

Currently there are regular steering group meetings with local partners: Natural England, Environment Agency, Rivers Trust, National Trust, and the National Park. Local farmers have been invited to join the project group, but none have joined yet. The Rivers Trust is having on-going discussions with farmers and landowners with regards to potential works for next year, depending on funding, The steeringr group decided that the most effective way of engagement was to continue with one to one visits and discussions, and if there was a demand to take small groups over to Long Preston to see works there when convenient for the farmers.

The final plan will be made available on the River Trust website and the Natural England website.

A Appendix

Appendix 1: Audit Photographs

The hydromorphic audit, conducted on the 6th, 7th and 8th July 2012, surveyed the river and floodplain between Hubberholme and the Skirfare confluence. This included a survey of the bed, banks, bar features and floodplain of the river to identify the existing morphological characteristics, processes sediment sources and sinks, structures, historic channel modifications and the state of the riparian zone. The audit was undertaken by experienced geomorphologists and the features were recorded and photographed using a GPS-based system. The photographs are presented in this Appendix.

Appendix 2: Hydraulic Modelling

Appendix 3: Phase 1 River Corridor Maps

The results of the ecological survey were mapped, to Phase 1 Habitat standard, to represent the habitats present along the surveyed section of river.

Appendix 4: Ecological Audit

The ecological survey, conducted on the 26th and 27th July and the 14th August 2012, surveyed the river and floodplain between Hubberholme and the Skirfare. This included a survey of the bed, banks, bar features and floodplain of the river to identify the flora and fauna present along the river and functional relationships between the biota and the morphology.

Appendix 5: Hydromorphic Audit Features

The hydromorphic audit, conducted on the 6th, 7th and 8th July 2012, surveyed the river and floodplain between Hubberholme and the Skirfare confluence. This included a survey of the bed, banks, bar features and floodplain of the river to identify the existing morphological characteristics, processes sediment sources and sinks, structures, historic channel modifications and the state of the riparian zone. The audit was undertaken by experienced geomorphologists and the features were recorded and photographed using a GPS-based system.

Appendix 6: Restoration Options

Appendix 7: Protected, notable and invasive species

During the ecological survey, the presence of notable, protected and invasive species was recorded and subsequently mapped.

Appendix 8: Literature Review

Appendix 9: Historic Channel Change

A review of the position of the river channel has been undertaken using historic mapping. This shows the degree of channel movement from 1852 to the present day. Limited channel movement has been identified in most areas as it is believed that significant changes to the channel form including channel management began prior to this period.

Appendix 10: Hydromorphic and Ecological Audit report

Hydromorphological reaches were defined during the combined hydromorphic and ecological survey of the SSSI. A detailed description of each of these reaches is presented here.

Offices at

Atherstone
Doncaster
Edinburgh
Haywards Heath
Limerick
Newcastle upon Tyne
Newport
Northallerton
Saltaire
Skipton
Tadcaster
Wallingford
Warrington

Registered Office
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