Yorkshire Water Services

River Restoration Pilots

Cudworth Dyke: Baseline Geomorphological Assessment & Restoration Plan

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Ove Arup & Partners Ltd
Admiral House Rose Wharf
78 East Street
Leeds LS9 8EE
United Kingdom
www.arup.com

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		Name	Daniel Newton, Irantzu Lexartza	Sally German	Katherine Pygott
		Signature			
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			Prepared by	Checked by	Approved by
		Name	Irantzu Lexartza	Sally German	Katherine Pygott
		Signature			
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Executive Summary

Yorkshire Water Services (YWS) commissioned Arup to conduct an investigation into the appropriate measures to mitigate existing water quality and hydromorphological issues, in the Cudworth Dyke catchment. This investigation is part of the River Restoration Pilots aimed to assess the technical feasibility, effectiveness, and cost and benefits of a range of potential river restoration options to improve the ecological status of water bodies.

This report presents the results of the baseline geomorphological assessment and catchment restoration plan conducted as part of the restoration investigation. The study of existing information and the site geomorphological assessment of the catchment have found significant impacts in terms of water quality and hydromorphology. These impacts are a result of the historical development of the catchment and are most visible in terms of the high levels of siltation, low flow, low diversity of channel structure and characteristics and poor connectivity along the river. A summary of all issues observed in and around the river is presented and discussed.

The identified issues are related, and cannot therefore be effectively addressed in isolation. In particular, improving the hydromorphological condition of the water body (i.e. the combination of flow conditions, the physical characteristics of the water body and the processes taking place) contributes to mitigation of water quality and ecology issues. The restoration strategy takes a catchment-wide perspective, considering options that will have a wider benefit on the system.

The river has been divided into six key reaches for the purpose of this study, and the key characteristics and issues for each reach have been assessed. Generic restoration options have been presented for the existing issues as a step to develop a specific catchment restoration plan. Following progress meetings and stakeholder discussions Yorkshire Water has selected reach 1, located in Sandybridge Dyke at the upstream end of the study area, to focus the resources for the pilot investigation. Details for the restoration plan at Sandybridge Dyke are provided in the report, and include a combination of in-channel works and bank reprofiling, weir removal and channel meandering, with potential for wetland enhancement/creation. Benefits of works in Sandybridge Dyke, such as increased dissolved oxygen, improved diversity of flows, reduced sediment through-put, water filtration through reed beds, etc., are expected to be noticeable further downstream. This report is designed to allow the issues and suggested solutions in all the reaches to be taken forward as separate projects when partnerships time and money allow and are given in Appendix G.

These findings will inform the next stage of outline design and the subsequent detailed design and construction stages for the selected restoration options, as well as future monitoring requirements. Further work and considerations are outlined below

1 Introduction

1.1 Study Background and Objectives

Yorkshire Water Services (YWS) is funded in AMP5 to investigate solutions to achieve compliance with the Good Ecological Status/Potential (GEP) of water bodies, as defined within the UK River Basin Management Plans (RBMPs) under the EU Water Framework Directive (WFD).

The overall investigation will use catchments associated to YWS assets to establish the technical feasibility, effectiveness, and costs and benefits of a range of potential river restoration options to improve the ecological status of water bodies. The investigation is focused on identifying appropriate measures to mitigate existing water quality and hydromorphological issues and assessing their effectiveness.

1.2 Scope of Report

This report summarises the following components of work undertaken for Cudworth Dyke:

- Collation of available baseline information, EA consultation relating to the WFD status and objectives of the waterbody (including existing EA biological monitoring datasets), and knowledge provided by stakeholders;
- Field-based, baseline fluvial geomorphological assessment of the watercourse within the study area (including photographic survey and GIS mapping of field data collected during a site visit and walkover survey);
- A Restoration Plan for the identified river restoration site within the study area (including identification of key issues, constraints, opportunities and risks at the site and development of high-level, potential restoration options).

These components of work will in turn inform outline design, detailed design, further stakeholder engagement, and baseline biological monitoring works for the proposed restoration sites.

2 Site Information

2.1 Site Extent and Description

The Cudworth Dyke catchment is located north east of Barnsley (Figure 1). Cudworth Dyke itself is 7.6 km long, and it drains an area of approximately 26.6km^2, including the urban areas of Royston, Carlton, Shafton and Cudworth.

The catchment is mostly located within the Pennine Middle Coal Measures formation, with alternating Carboniferous mudstones, siltstones and sandstones. Superficial alluvial deposits are found along the river corridor, with clays and silts forming up the floodplain.

The channel has generally a low gradient. There is a mixture of urban, industrial and agricultural land uses within the catchment, with significant mining activity in the past, mostly in the upstream part of the catchment. Immediately adjacent to the waterbody a mixture of farmland, parkland/recreation areas and urban/industrial uses can currently be found. Substantial restoration (post mining activity) has taken place in the catchment, mostly in Rabbit Ings and Carlton Marsh.

The potential route for HS2 to Leeds passes across the site; a route section is provided in Appendix J for information.

Several YW assets can be found on the watercourse, including two sewage water treatment works and a variety of CSOs, pumping stations and outfalls. A map of these is included in Appendix H. YW's UPM Study (2013) concludes that YW assets along this stretch of watercourse are compliant with their consents and YW is currently awaiting approval from the EA. The watercourse is however currently non-compliant with the WFD requirements of good ecological status, as discussed in Section 3.

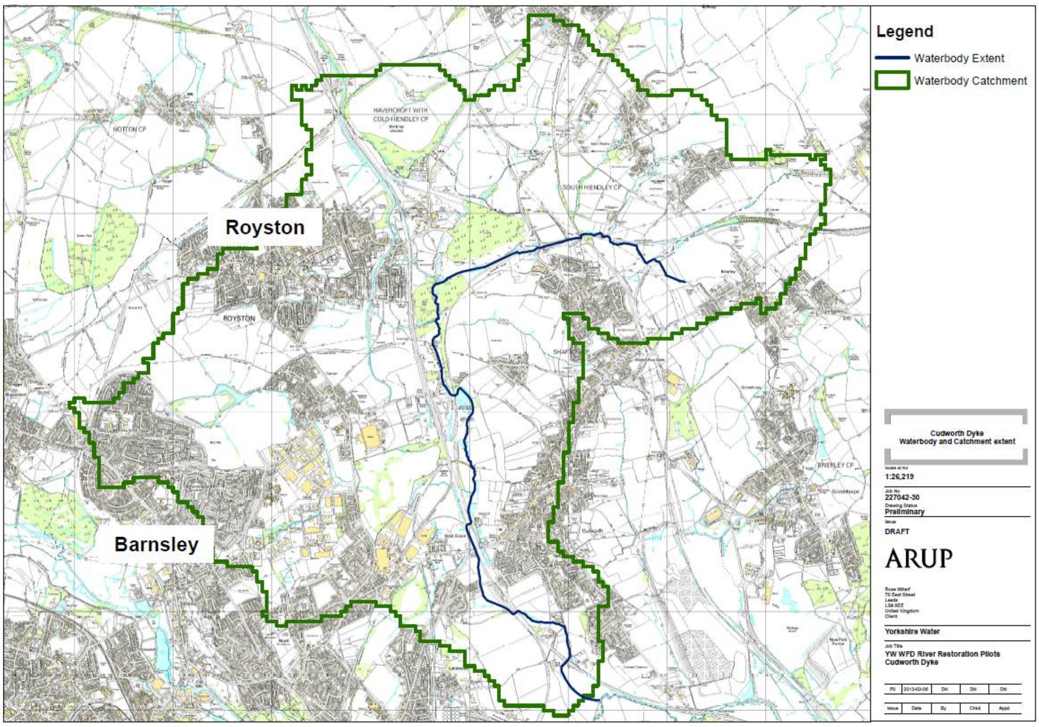


Figure 1 Location map and extent of Cudworth Dyke waterbody and catchment.

3 EA WFD Information

3.1 Waterbody Status and Objectives

Cudworth Dyke from Source to River Dearne (GB104027063230) is not designated as a Heavily Modified Water Body, although several quality elements have been assessed as bad, poor or moderate. The objective for this water body is to achieve Good Ecological Status by 2027 (see Appendix A for waterbody WFD objectives).

The waterbody status is currently Moderate and therefore in non-compliance with the WFD overall aim of Good Ecological Status (GES). The factors considered to be causing non-compliance are those Quality Elements presently classified as Bad, Poor or Moderate status (including macroinvertebrates, ammonia, dissolved oxygen and phosphate) as detailed in Table 1.

Table 1 Current Status of the Cudworth Dyke waterbody (EA, 2011[1])*

Quality Elements	2009/10 Status	2011 Status
Biological Status:		
Macroinvertebrates	Bad	Moderate
Phytobenthos	No Assessed	Moderate
Physic-Chemical Status:		
Ammonia	Bad	Bad
Dissolved Oxygen	Poor	Poor
pH	High	High
Phosphate		Moderate
Temperature	High	High
Hydromorphological Status:		
Hydrology	Good	Good
Morphology	Good	Good
Specific Pollutants:		
Copper	High	High
Zinc	High	High

Status	
High	
Good	Target Status (2027)
Moderate	Current Status (2011)
Poor	
Bad	Previous Status (2009/10)

**note: WFD Status Classification updated again in 2012 (data not yet available)*

Some key pressures that have been identified within the catchment that are likely currently impacting on ecological status are: agricultural and urban runoff; historical and present industrial pollution (including potentially contaminated sediments); CSOs and WTWs; culverts and in-channel structures; channel realignments; excessive vegetation and invasive species.

Cudworth Dyke is designated as a protected area under the Freshwater Fish Directive and the Nitrates Directive.

3.2 Assessment and Reasons for Failure

Data resulting from monitoring conducted by the Environment Agency at Cudworth Dyke is available for different dates and locations.

Over different timescales, the Environment Agency has conducted monitoring at various sites across the catchment. EA Invertebrate monitoring has been conducted at eight separate sites along the waterbody (Sandybridge Lane, downstream of Sandybridge, downstream of Coking Works, downstream of Rabbit Ings, Pools Ings, Boulder Bridge, downstream of Cudworth STW and downstream of Cudworth Carrs Lane), although monitoring has only been relatively continuous at the downstream site of the water body.

[1] Environment Agency, 2011. Classification Objectives for WFD Cycle 1, updated January 2011. Excel document.

EA Water quality monitoring has been carried out at five sites: downstream of Royston CSO, downstream of Pools Lane CSO, Boulder Bridge, downstream of Ryder & Green and Wood Nook Farm. Limited diatom monitoring has also taken place downstream of Cudworth SWT works.

The level of certainty (evidence base from biological monitoring data) for elements failing is stated as high (Very Certain or Quite Certain).

Main reasons for failure are identified as suspected and confirmed pressures impacting water quality (diffuse and point source), confirmed pressures impacting the river sediment regime (point source) and confirmed pressures impacting morphology. Invertebrate monitoring may be skewed towards the downstream part of the waterbody. More detailed information regarding EA WFD monitoring and assessment of reasons for failure is provided in Appendix A.

4 Catchment Assessment

4.1 Methodology

This section provides an overview of the techniques that were used in order to acquire and appraise geomorphological data for Cudworth Dyke.

A desk study of historical and contemporary maps, existing asset information and GIS data was used to attain an initial understanding of the system and inform data requirements for the field survey.

A geomorphological walkover of a river section extending from Sandybridge Dyke to downstream of Carlton Marsh Nature Reserve was undertaken over three separate dates, on 28th September, 23rd November and 5th December 2012. The walkover survey included photographic surveys and field mapping of key geomorphological features. The extent of the study area covered during the site work is shown in Figure 3.

The assessment characterised the watercourse into separate physical geomorphological reaches based on key indicators of geomorphological change, including; significant changes in bed and bank material, channel planform and geometry, channel gradient, dominant processes, adjacent land use and riparian character, and the presence of artificial structures.

Fluvial habitat sub-reaches were then identified according to variations in dominant flow types. Information regarding substrate material and size, and in-channel vegetation was collected for each of these habitat reaches where visible. Spatial information relating to types and locations of bank erosion, bank protection, channel inflows, sediment input sources, and the presence of key features such as sediment bars and artificial structures was also recorded. In addition, observations were made on channel geometry (including width and cross-sectional form) and floodplain topography. Natural erosion and depositional features were also recorded as they provide variability in channel morphology and are indicative of an active and dynamic river system.

4.2 Stakeholder Consultation

Stakeholders were a key source of relevant information about the Cudworth Dyke catchment. Two formal workshops have taken place. The first one, on 19 October 2012, was used to collate information and knowledge held by the stakeholders and discuss opportunities and constraints. At the second workshop, held on 6th March 2013, the findings of the catchment study were presented and a catchment plan for Cudworth Dyke was discussed.

Relevant stakeholders were also met on-site at specific reaches/areas of interest during the walkover surveys.

A list of stakeholders who attended the workshops and have been consulted with directly is provided in Appendix B.

4.3 Historical Assessment

An assessment of historical change was conducted using several historical maps ranging from 1855 to present. Significant aspects that were considered were those related to land-use change and changes of the river corridor and planform. These are discussed in detail below. Information provided by stakeholders was also useful at this stage.

4.3.1 Overview of catchment land-use change

Land use has changed significantly in the last 150 years in the Cudworth Dyke catchment, with many of the changes having a significant effect on the water body. An overview of such changes is shown in Figure 2 and details of the evolution of specific land uses and changes at every reach are given in Appendix C. Most of the land in the mid-19th century was farmland, with small urban settlements around Royston and Cudworth and small quarries/colliery sites in the NE of the catchment.

By the 1930s, Monkton Main Colliery and Rabbit Ings tip had fully developed, with other smaller colliery sites in the catchment, as was the railway network in the area. Urban areas in the catchment had expanded significantly. Such changes are likely to have had significant impacts on water quality and sediment transfer.

Sewage treatment was improved in the area after WW2, with sewage works at Lund Hill, Pools Ings and Sandy Bridge. In the 1970s the scrapyard site was established in Boulder Bridge Lane. Carlton Marsh Nature Reserve was created and the river diverted to disconnect it from the existing scrapes due to the significant pollution issue of the stream, accentuated by the scrapyard site immediately upstream of the nature reserve.

The railway line that was part of the North Midland railway and ran the length of 13.2 km between Cudworth and Royston from south to north with another line east of Royston has now been fully dismantled and partly transformed to footpaths. The Monkton Main Colliery has been reduced to a smaller processing plant and the Rabbit Ings tip has been restored to a parkland area.

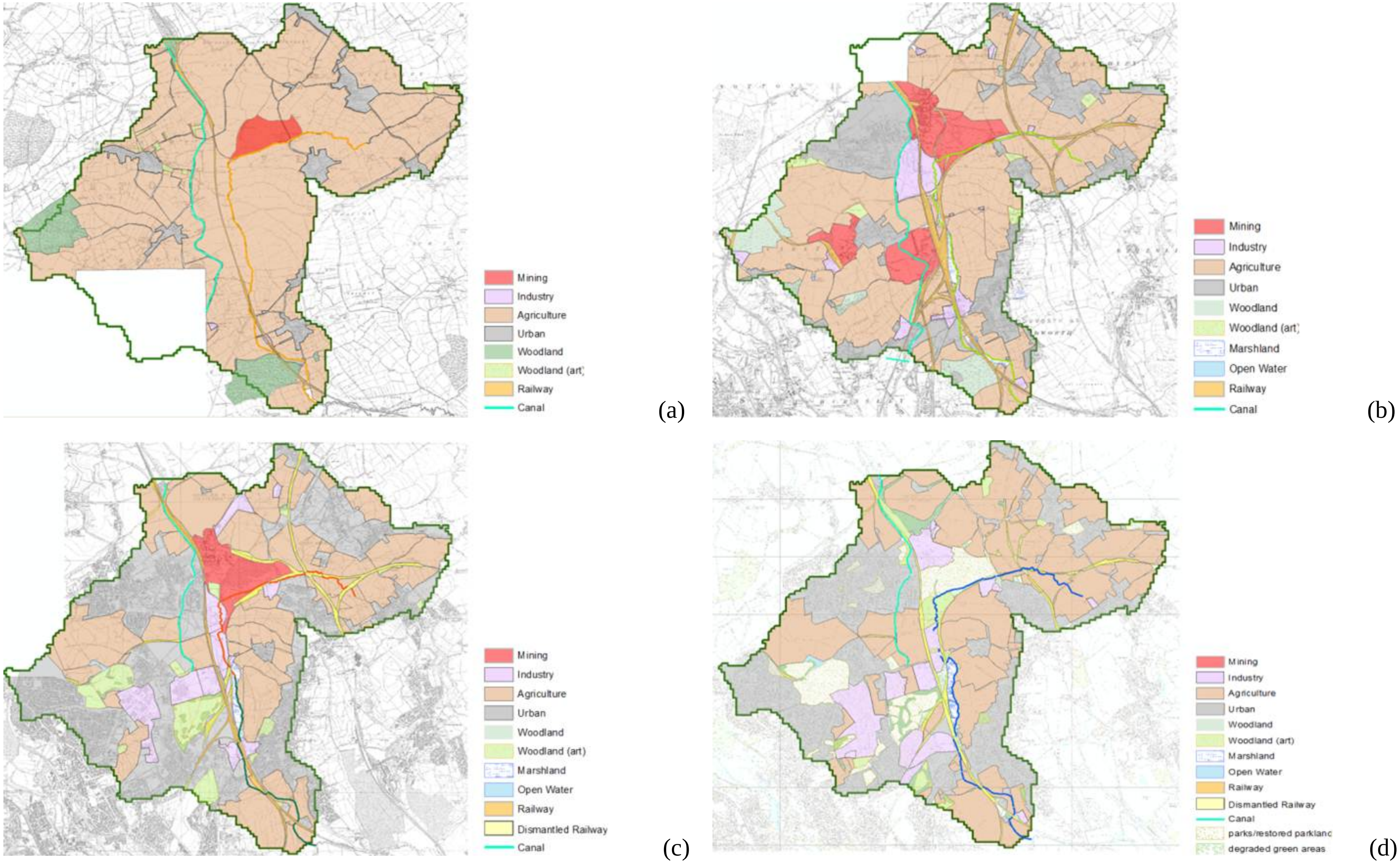


Figure 2 Evolution of historical land-use change, showing a progression from a dominant agricultural use to the development and disappearance of mining and the expansion of urban settlements: (a) 1855, (b) 1938, (c) 1981 and (d) present.

4.3.2 Overview of channel-corridor changes

Most of the changes experienced by the river corridor are related to the different land use activities in the catchment. The most significant changes have been channel diversions, localised straightening/realignment and widespread culverting (see Appendix C).

Most localised straightening of the channel appears to be related to the railway line and crossings, as are some of the smaller culverts in Sandybridge Dyke, Pools Ings and near Boulder Bridge. The biggest current culvert is located in Boulder Bridge and is related to the industrial activity at the scrapyards.

Significant channel diversion took place at Carlton Marsh to disconnect the channel from the nature reserve scrapes due to the low water quality; although at high water flow there are episodes in which the stream breaches into the scrapes.

4.4 Geomorphological Assessment

This section presents a baseline geomorphological assessment that provides an understanding of the prevailing fluvial form and processes of the site, together with the dominant geomorphological controls and influential factors at the reach scale. The understanding attained by this assessment provides a geomorphological baseline, which can be used to determine a restoration plan.

Weather conditions on the day of the first site visit were overcast with rainy spells. River flows were relatively high and aquatic and riparian vegetation heavily overgrown in places. Weather conditions were sunny and cold both on the second and third visits and most of the vegetation had died back.

The geomorphological data collected during the walkover survey are provided in more detail in Appendix D and have been transferred into an ArcGIS dataset provided separately. Photographs taken during the geomorphological walkover are provided in Appendix E.

4.4.1 Broad catchment characterisation

Cudworth Dyke is dominated by a generally low geomorphological diversity. Flows are very homogenous, dominated by runs or glides except for limited areas where in-channel features (e.g. woody debris dams) have a localised impact on the flow. The channel is mostly trapezoidal, overwide and overdeep, with significant bank erosion observed in several points.

One of the most noticeable characteristics of the Cudworth Dyke catchment is its poor sediment transfer regime, with excess in-channel siltation found throughout most of the study section. This accumulation of fine sediments has a great negative impact on in-channel habitats and geomorphological processes. In-channel geomorphological features are mostly ‘hidden’ by the overlying fine sediment layer.

The river is relatively flashy, responding quickly to rainfall events with significantly increased flows. Areas of low gradient, either natural or related to channel diversion/lengthening, show a significant stagnation of flow and significant in-channel vegetation. The sediment deposition issue is accentuated in these low gradient areas.

Substantial riparian vegetation overgrowth is observed in some areas, while a lack of vegetation cover is found in others. Presence of invasive species has been recorded by YWS at several locations in the catchment (see Appendix F)

4.4.2 Reach overview

The study area was divided in six geomorphological reaches based on their characteristics (Table 2). The location and extent of the reaches is shown in Figure 3.

Table 2 General characteristics of the geomorphological reaches defined at the walkover survey.

No.	Reach	Length	Av. width	Dominant flow type	Dominant substrate	Structures
1	Sandybridge Dyke	860m	2.5-3m	Run	Fines	1 weir 7 debris weirs 2 weirs (1 collapsed) 1 culvert
2	Pools Dyke	350m	2.5-3m	Run	Fines	2 culverts
3	Pools Lane CSO	205m	4-5m	glide	Fines	1 outfall (CSO)
4	Boulder Bridge	760m	2.5-3m	Not accessible	Not accessible (coarser where visible)	4 culverts 2 weirs 1 outfall (trib)
5	Carlton Marsh	730m	4-5m	Glide/ ponded	Fines	1 trash screen
6	d/s Carlton Marsh	900m	3m	Run	Fines	1 footbridge

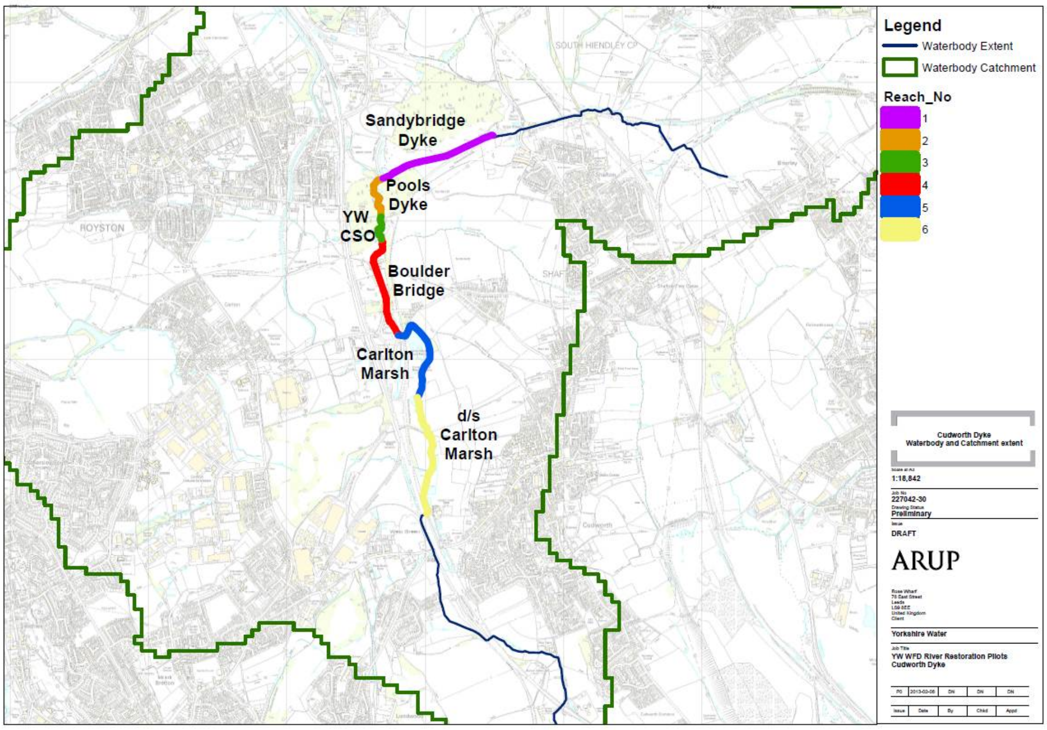


Figure 3 Defined geomorphological reaches within the walkover survey extent.

4.4.2.1 Sandybridge Dyke

This reach extends from Sandy Bridge to Pools Ings. It shows more sinuosity than is apparent from the topographic maps and there are a large number of debris dams within it. It is however, overdeep and overwide, with a trapezoidal channel and lacks diversity in its morphology and habitat (Figure 4). Siltation is observed along most of the reach. Some key characteristics of this reach are:

- Dominated by runs with many small cascades at debris dams
- Localised fluvial bank erosion, with some evidence of incipient meandering (within confines of floodplain topography).
- Extensive silty deposits ranging from 0.25m to 1m of silt over a coarser substrate.
- Channel incision, with steep banks in places, undercutting and poor floodplain connectivity, especially in the upstream section of the reach
- Dense riparian vegetation upstream
- Lack of riparian vegetation downstream
- Obsolete weir and sediment mound
- Large woody debris (LWD) dams and urban rubbish dams (tires, bath tubs, etc.).

Figure 4 Example view of the river at Sandybridge Dyke

High iron concentrations and arsenic levels have been identified at Sandybridge Lane by the Environment Agency, which could have an impact on water quality. Assessment of this issue is ongoing (personal communication YWS-EA).

4.4.2.2 Pools Dyke

This reach runs along Pools Ings (Figure 5), and several small restrictive culverts can be found within it. Main general characteristics/issues:

- Dominated by runs affected by narrowing effect of marginal vegetation
- Coarse substrates overlain by silty deposits, increasing in thickness towards the downstream section of the reach.
- High connectivity with floodplain (evidence of regular out-of-bank events)
- Dense riparian and marginal vegetation
- Ponding behind restrictive culverts at crossings
- Narrower upstream and wider and deeper downstream

Figure 5 Example of the river at the Pools Dyke reach

4.4.2.3 Pools Lane CSO

The most significant characteristic of this reach is its low gradient, which affects flow significantly, and is reflected by an increased level of siltation and in-channel vegetation (Figure 6). The main defining features are:

- Low gradient, flat floodplain
- Flows dominated by glides and ponded flow
- High amount of silty deposits within channel and along banks
- High connectivity with floodplain (evidence of regular out-of-bank events)
- Sinuous channel, overwide and overdeep
- Dense riparian, marginal and aquatic vegetation
- Inflow from canal overflow tributary and CSO

Figure 6 Example view of the river at the Pools Lane CSO reach

4.4.2.4 Boulder Bridge

Most of the river is culverted within this reach, and consequently geomorphological characteristics could not be observed (Figure 7). The culvert runs underneath a scrapyard site with direct runoff into the waterbody and consequent water quality impacts. Key characteristics of this reach are:

- 20m long culvert under old railway embankment at upstream end of reach
- 200m twin concrete pipe culverts under scrapyards
- Where visible, channel narrower, channelised/confined
- Where visible, fast flowing runs with coarse substrates
- Urban rubbish and direct surface runoff from scrapyards and roads

Figure 7 Example view of the river at the Boulder Bridge reach

4.4.2.5 Carlton Marsh

This reach is within Carlton Marsh Nature Reserve. In the past the original channel was diverted around a constructed wetland area due to the low water quality of the river, to prevent pollution to the wetland (Figure 8). The diverted channel is significantly longer than the original, and thus the gradient has been considerably reduced. The channel at Carlton Marsh is defined by:

- Sluggish flow, glides or ponded
- Diverted channel, informal embankments along right bank to disconnect from scrapes
- High siltation (>1m) in bed
- Lack of diversity in flow and morphology
- Densely vegetated, with willows encroaching channel and wetland
- River reverts to historic route during high flow events, breaching right bank immediately downstream of culvert exit. This causes significant pollution incidents for main scrape

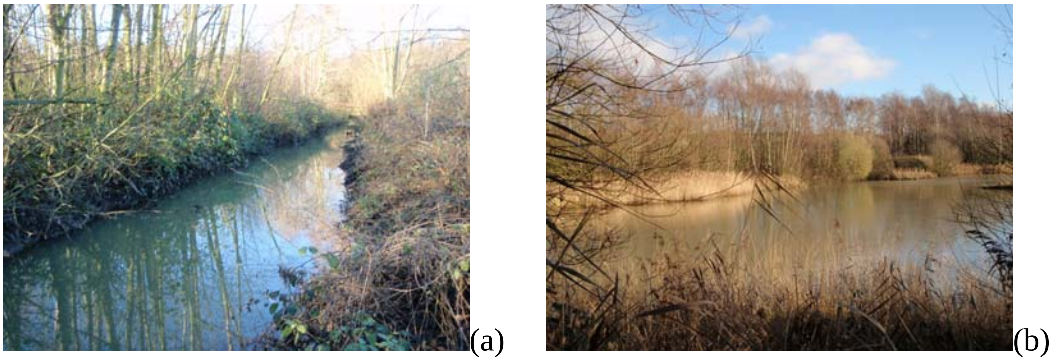


Figure 8 View of (a) diverted channel and (b) existing scrapes at Carlton Marsh

4.4.2.6 Downstream of Carlton Marsh

This reach shows a significant change from Carlton Marsh (Figure 9), with increased flow diversity and going from a dense riparian vegetation cover to a lack of a riparian buffer. The following are the main defining characteristics:

- Dominated by runs but shows more flow diversity than reaches upstream
- Less silt deposits along bed (fine and coarse sediments visible)
- Localised overdeepening and overwidening
- Lack of riparian vegetation downstream
- Sediment delivery along left bank due to surface runoff from fields and poaching by horses
- Good connectivity with floodplain in lower half, with existing floodplain wetland features

Figure 9 Views of the river at the reach downstream of Carlton Marsh

4.5 Baseline Biological Monitoring

Baseline biological monitoring has been conducted at Cudworth Dyke (Figure 10) for macroinvertebrates, macrophytes and fish (fish monitoring was abandoned due to negligible results and health and safety concerns). Ecological monitoring variables have been focused in-line with the relevant biological quality elements included in the Assessment of Good Ecological Status/Good Ecological Potential of waterbodies within the present Humber River Basin Management Plan (RBMP). Community assemblages of these indicators can be used to provide an estimate of waterbody health, and as they are sensitive to changes in chemical and physical conditions they will reflect changes within the waterbody. The monitoring was designed in order to be able to assess the impacts of any river restoration intervention on these key indicators of ecological status. Baseline monitoring is a key element that will allow evaluating any potential improvements of river restoration on the monitored indicators.

Monitoring results will be reported on, in more detail, separately, but preliminary results based on macroinvertebrate data from autumn 2012 suggest poor status for most of the catchment. For Sandybridge Dyke and Pools Ings, based on macroinvertebrate data from autumn 2012 and spring 2013, results suggest poor status for most sites. Sandybank was classified as Moderate in autumn 2012 and is likely to be classified as Poor in spring 2103.

A high level interpretation is that the composition of invertebrate assemblages is being influenced away from their expected population by a/several factor/s in the catchment. Given that the WFD classification is fundamentally based on BMWP scores (where species are scored against their tolerance of water quality), and that LIFE scores (where species are scored against their flow tolerances) are generally acceptable, it is likely that measures taken to improve water quality may improve the WFD class of the reach based on macroinvertebrates.

As part of the ongoing project, the results are being fully analysed together with macrophyte data and existing water quality data to provide the interpretation for the full baseline monitoring report. Further details on baseline ecological monitoring at Cudworth Dyke are presented in Appendix I.

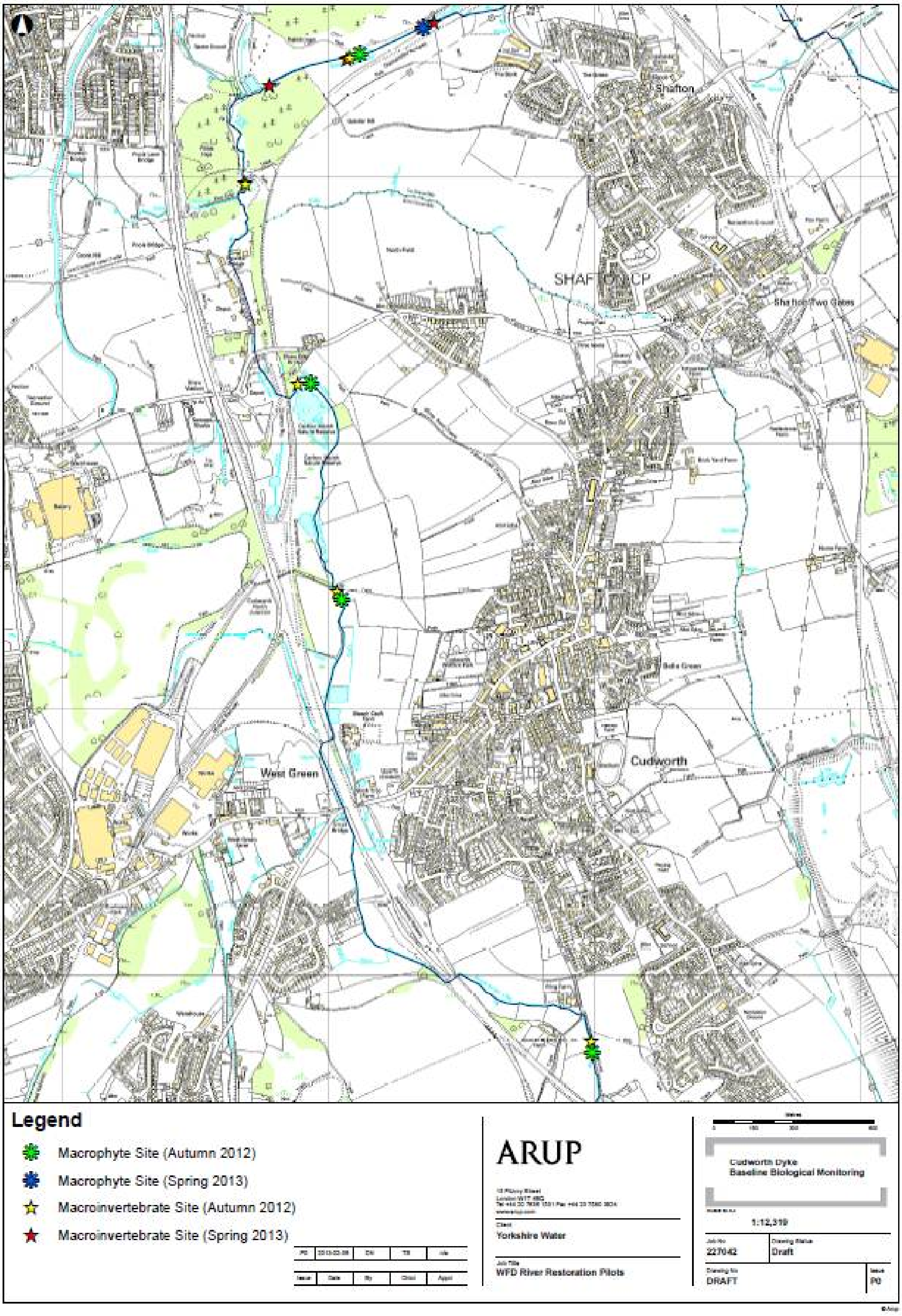


Figure 10 Baseline monitoring sites.

4.6 Additional ecological information

Yorkshire Wildlife Trust (YWT) has conducted ecological surveys in the Cudworth Dyke catchment, including records of invasive species and protected species such as water voles, which should be taken into consideration for any restoration project. Information on additional ecological data is provided in Appendix F and in data accompanying this report.

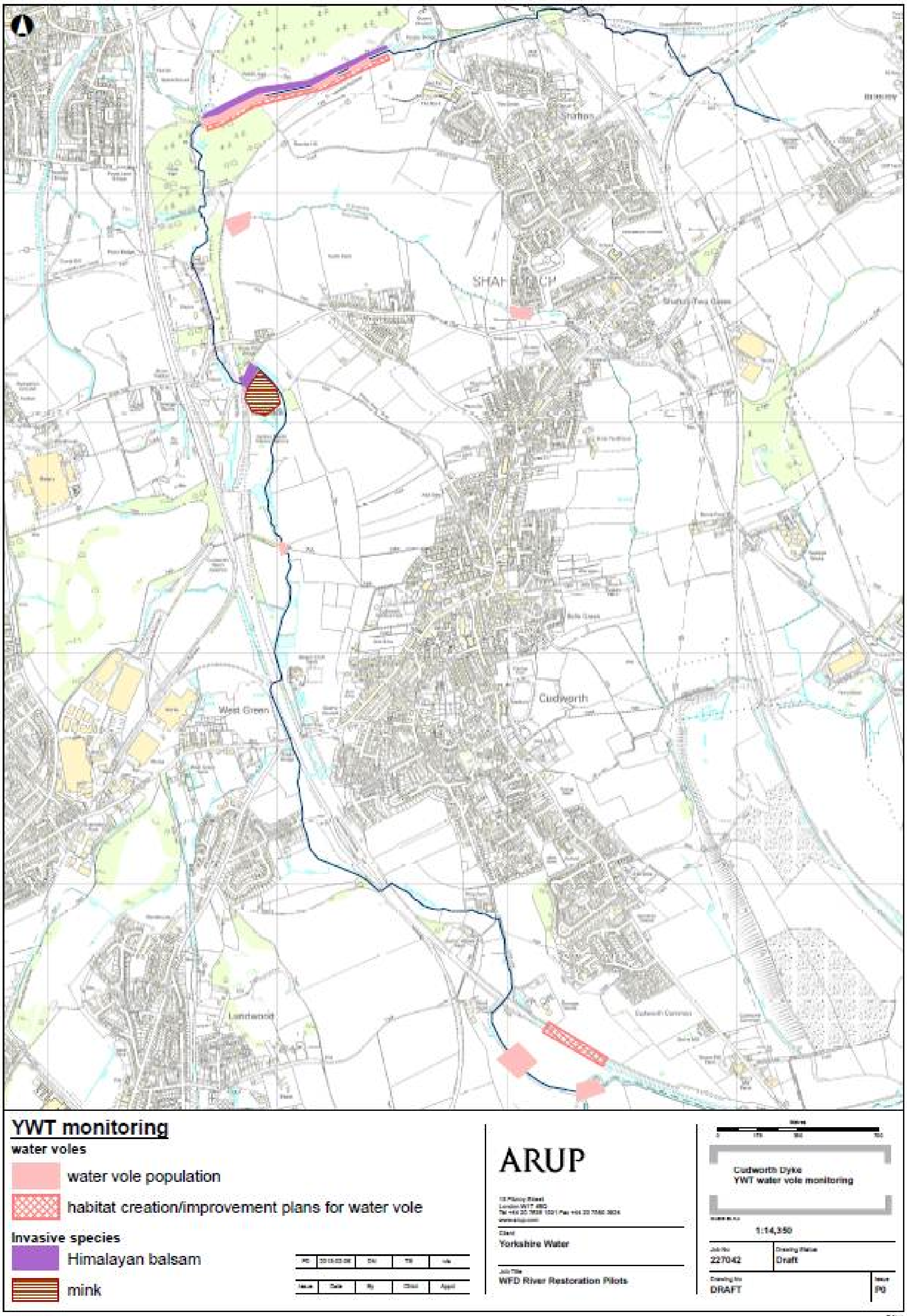


Figure 11 biological monitoring by the Yorkshire Wildlife Trust

5 Restoration Strategy

5.1 Purpose

The purpose of the proposed restoration strategy is to address the existing ecological/geomorphological quality issues in Cudworth Dyke through the implementation of a range of river restoration techniques. The aim will be to test the technical feasibility, effectiveness, costs and benefits of river restoration options as a tool to improve ecological status.

The identified issues are related and cannot therefore be effectively addressed in isolation. Furthermore, hydromorphological condition, biological processes, and water quality are closely interconnected, and thus improving the hydromorphological condition of the water body can also contribute to mitigation of water quality and ecology issues. It was agreed by YWS, its partners and stakeholders that the restoration strategy should have an integrated approach. The restoration strategy takes also a catchment-wide perspective, considering options that will have a wider benefit on the system.

5.1.1 Summary of key issues

A summary of the identified key pressures addressed by the restoration strategy is presented in Table 3. Many of the pressures are widespread within the catchment, and a range of options to address them will be discussed below.

Table 3 Key pressures and impacts in the Cudworth Dyke catchment

Pressure	Impacts
Excessive riparian and in-channel vegetation	Excessive shading (impacts on physic-chemical parameters and biological indicators); Impacts on channel morphology (e.g. in-bank trees promoting localised scour and bank failures); Impact on flow and geomorphological processes (e.g. coarse woody debris dams and in-channel trees promoting sediment deposition and back-ponding and upstream, localised bed and bank scour downstream)
Sparse riparian vegetation	Lack of tree cover, exposed channel (impacts on physic-chemical conditions and biological indicators); Access for livestock leading to poaching, bank degradation and sediment inputs; No buffer against surface runoff
High sediment supply and siltation	Water quality impacts related to agricultural runoff and urban/industrial runoff sources; Sources from bank erosion and channel scour; Impacts on channel morphology (suffocation of bedforms) and related impacts on flow and geomorphological processes; Loss of habitat quality
In-channel structures (culverts and weirs)	Impacts on biological and sediment connectivity (e.g. fish passage and sediment transport downstream); Impacts on local hydromorphology (water levels, ponding and siltation upstream, scour downstream);

	Impacts on flood risk (restriction to high flows, blockage risk); Impacts on local physic-chemical parameters and/or direct loss of aquatic habitat; Reduced potential for natural channel adjustment processes (lateral and longitudinal)
Channel morphology (artificial modifications: channel diversion and local straightening)	Lack of morphological diversity; Trapezoidal channel form, over-deepening; Limited diversity in flow types and aquatic habitat conditions; Poor connectivity with floodplain; Reduced gradient (diversion), promotion of channel incision during high flows (straightening)

To these more general pressures, sporadic issues such as pollution incidents or geographically limited problems such as high iron concentrations in the upstream reach of the water body have to be added.

5.2 Summary of Potential River Restoration Solutions

Considering the identified pressures and their impacts, a range of river restoration solutions applicable to the Cudworth Dyke catchment have been identified. The proposed solutions and their benefits in dealing with the existing catchment impacts have been listed in Table 4.

Table 4 Potential solutions (more information on River Restoration methods can be found, for instance, on the River Restoration Manual[2] and the STREAM River Restoration Advice Note[3])

River Restoration Solution	Main Benefits
Vegetation management Selective clearance	Reduce excess shading to improve flows, dissolved oxygen levels and conditions for the establishment of more appropriate ecological assemblages; Reduce bank degradation, scour, ponding of flows, etc., to provide improved flows and increased dissolved oxygen levels and provide better marginal habitats, thus improving habitat conditions and water quality; Control of invasive species to improve conditions for improved ecological assemblages; Additional benefit of improved amenity value
Vegetation management Marginal / riparian planting	Reduce excessive channel exposure to reduce the amount of sediments being delivered into the channel and protect aquatic habitats; Provide refugia and feeding habitat for aquatic species by providing a more heterogeneous system, thus improving the ecological assemblages and status of the river; Stabilise banks and reduce fluvial erosion and poaching to reduce the amount of sediments and sediment associated pollutants being delivered into the channel and protect aquatic habitats;

[2] STREAM River Restoration Techniques Advice Note, Shttp://webarchive.nationalarchives.gov.uk/20101118120645/http:/www.streamlife.org.uk/resources/publications/
[3] River Restoration Manual, RRC, http://www.therrc.co.uk/rrc_manual.php

	Buffer direct surface runoff to reduce the amount of sediments and sediment and runoff associated pollutants being delivered into the channel
Bank re-profiling / rehabilitation	Increase morphological variability, providing improved aquatic, marginal and riparian habitats for biological indicators; Increase hydromorphological diversity (flow depths, velocities, sediment dynamics), improving thus more diverse flow dynamics and increasing dissolved oxygen levels in the system; Reduce bank erosion and associated sediment input to the channel to reduce the amount of sediments and sediment associated pollutants being delivered into the channel; Promote formal sediment deposition zones, stabilised by marginal vegetation growth, to reduce the release of fine sediments and sediment associated pollutants into the system, thus improving habitat conditions and water quality;
Bed raising	Reduce water depths and increase flow turbulence to increase oxygenation of water column; Reduce siltation and encourage entrainment of fine sediments to improve aquatic habitat conditions for benthic species, provide spawning habitat for fish, and reduce the release of sediment associated pollutants into the channel;
Removal / modification of structures	Improve biological and sediment continuity to improve flows and allow the migration of fish and other species; Reduce ponding and siltation upstream of structures to increase oxygen levels and improve flows; Reduce scour downstream to prevent the release of excess fine sediments and sediment associated pollutants into the system; Restore channel gradient and potential for natural channel adjustment (weir) to improve potential for fish passage and restore local channel and riparian habitats;
Channel restoration / creation	Purpose designed channels can be used to enhance hydromorphological conditions (flow diversity and sediment dynamics), increase oxygen levels and improve aquatic habitat and wider biodiversity value Restore previously modified/degraded channel sections, or to bypass existing structures such as culverted sections, improving connectivity and fish passage and providing more natural habitats; Opportunities for incorporating additional benefits (e.g. amenity features, flood storage features, wetland features, etc.)
Reed beds and online attenuation ponds	Buffer surface runoff and associated sediments/pollutants (reed beds), filtering or diluting inflows to improve water quality; Provide refugia and feeding habitats for aquatic species and improve wider biodiversity value; Potential for additional flood storage benefits (online attenuation ponds)
Floodplain / riparian restoration	Improve riparian and floodplain habitat quality and re-naturalise hydrologic regime to improve water quality and wider biodiversity by providing improved buffer and diversity; Potential for additional flood storage, aesthetic and amenity benefits

Creation of in-channel features	Increase flow-type diversity by increasing local flow velocities and turbulence, providing thus improved dissolved oxygen levels; Create features to support an improved distribution of fine and coarse sediments to improve flow and habitats; Create features to trap and immobilise existing fine sediments to reduce the amount of fine sediment and sediment associated pollutants released into the system and improve benthic habitats; Improve benthic, aquatic and marginal habitat quality

5.3 Proposed Restoration Plan

Considering the existing pressures and the available potential solutions, a catchment plan was proposed and discussed with stakeholders (Figure 12).

A phased restoration approach has been suggested, with four phases, starting at the upstream end of the study area:

- Phase 1- Sandybridge Dyke
- Phase 2- Pools Dyke and Pools Lane CSO
- Phase 3- Boulder Bridge
- Phase 4- Carlton Marsh

The area of intervention identified by YWS to concentrate their resources for the River Restoration Investigation is Sandybridge Dyke (Phase 1), with potential for collaboration with Groundwork at Rabbit Ings. Given its location in the upstream end of the water body, improvements in this reach could have wider benefits for the downstream areas, such as increased dissolved oxygen in the system from improved flows, increased energy, reduced fine sediment input, etc. Coordination of the stakeholder group will continue to discuss the subsequent restoration phases, and details of the restoration plan and a summary of opportunities and constraints for each reach are provided in Appendix G.

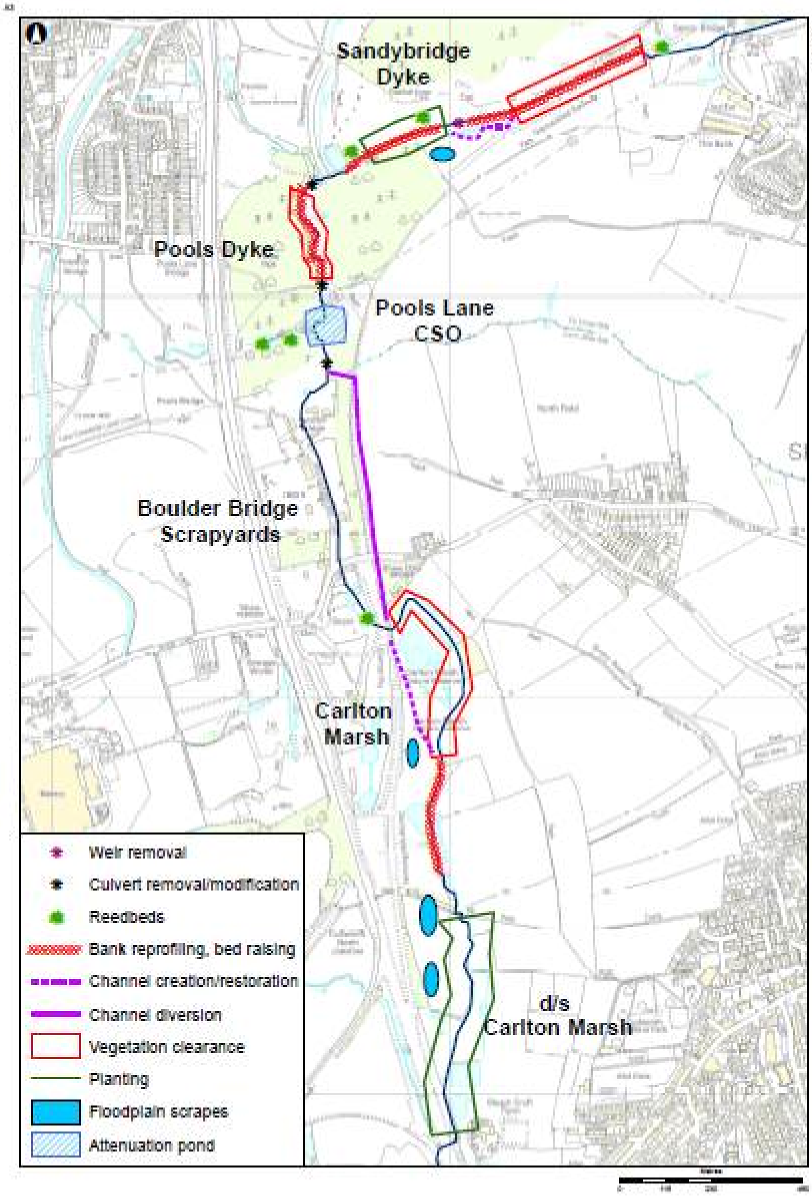


Figure 12 Proposed catchment restoration plan for Cudworth Dyke.

5.3.1 Detailed options for Sandybridge Dyke

A range of restoration options that could be implemented in conjunction with each other, and that could be enhance by wider restoration of Rabbit Ings, have been proposed (Figure 13) and are detailed below:

Vegetation Management, including:

- Selective clearance of riparian and marginal vegetation in the upstream section;
- Some riparian planting downstream;

Localised **bank reprofiling** and **bed raising** along the whole reach:

- Potentially making use of existing excess silt accumulations. Further investigation should ascertain whether silt could be kept in-situ and if import of gravel material may be necessary;

Weir removal, including:

- Physical removal of the structure;
- Localised bed regrading and bank reprofiling;

Reed beds:

- Enhancement at existing location and introduction at new locations;

Open water features:

- Enhancement of existing features;
- Potential to create open water features to increase floodplain diversity;

Channel diversion / remeandering:

- Potential to create a more sinuous section of channel, depending on spatial and land ownership constraints

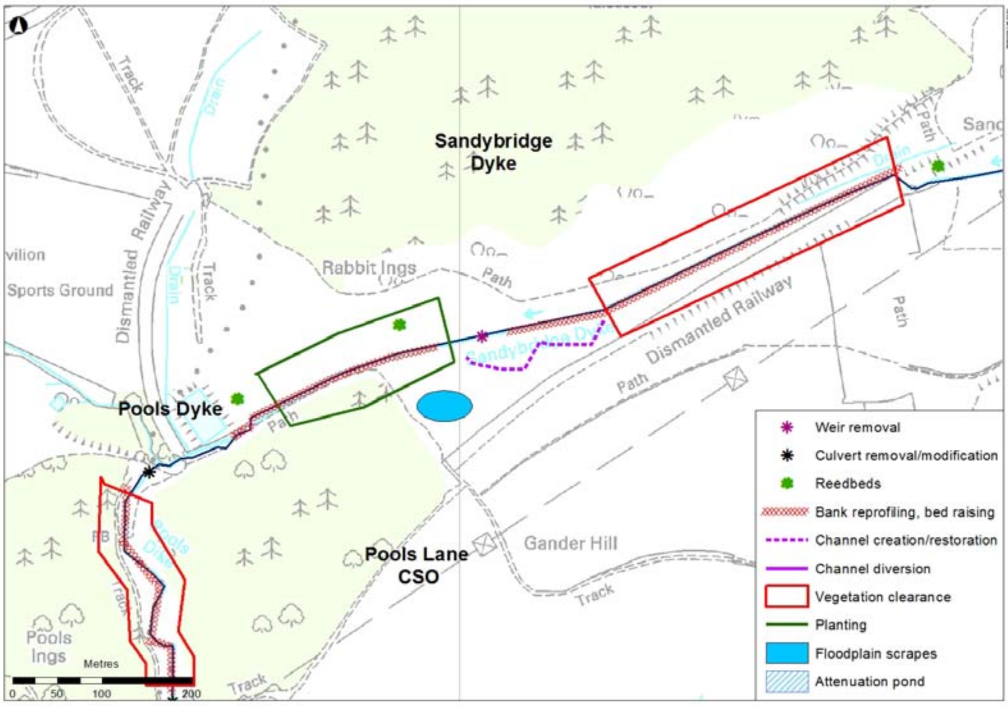


Figure 13 Mapping of restoration options for Sandybridge Dyke

5.3.1.1 Constraints and opportunities:

Current land owners (the Land Trust and BMBC) are supportive of the restoration plans for Sandybridge Dyke and the relatively easy access to the vicinity of the channel should facilitate the Implementation of the proposed restoration options. Some potential constraints will need to be clarified during the outline design stage. The main identified opportunities and constraints are listed below:

Opportunities:

- Landownership is clear and access permissions have been given on north floodplain (Land Trust owned land) and south floodplain (BMBC land);
- Floodplain topography at downstream end of reach provides a potentially suitable area to increase sinuosity of the channel by remeandering and to add habitat features;
- Potential for collaboration with The Land Trust at Rabbit Ings;
- Potential for improvements through HS2, should the route be confirmed; this is however a very long-term horizon and is subject to government decision making.

Potential constraints:

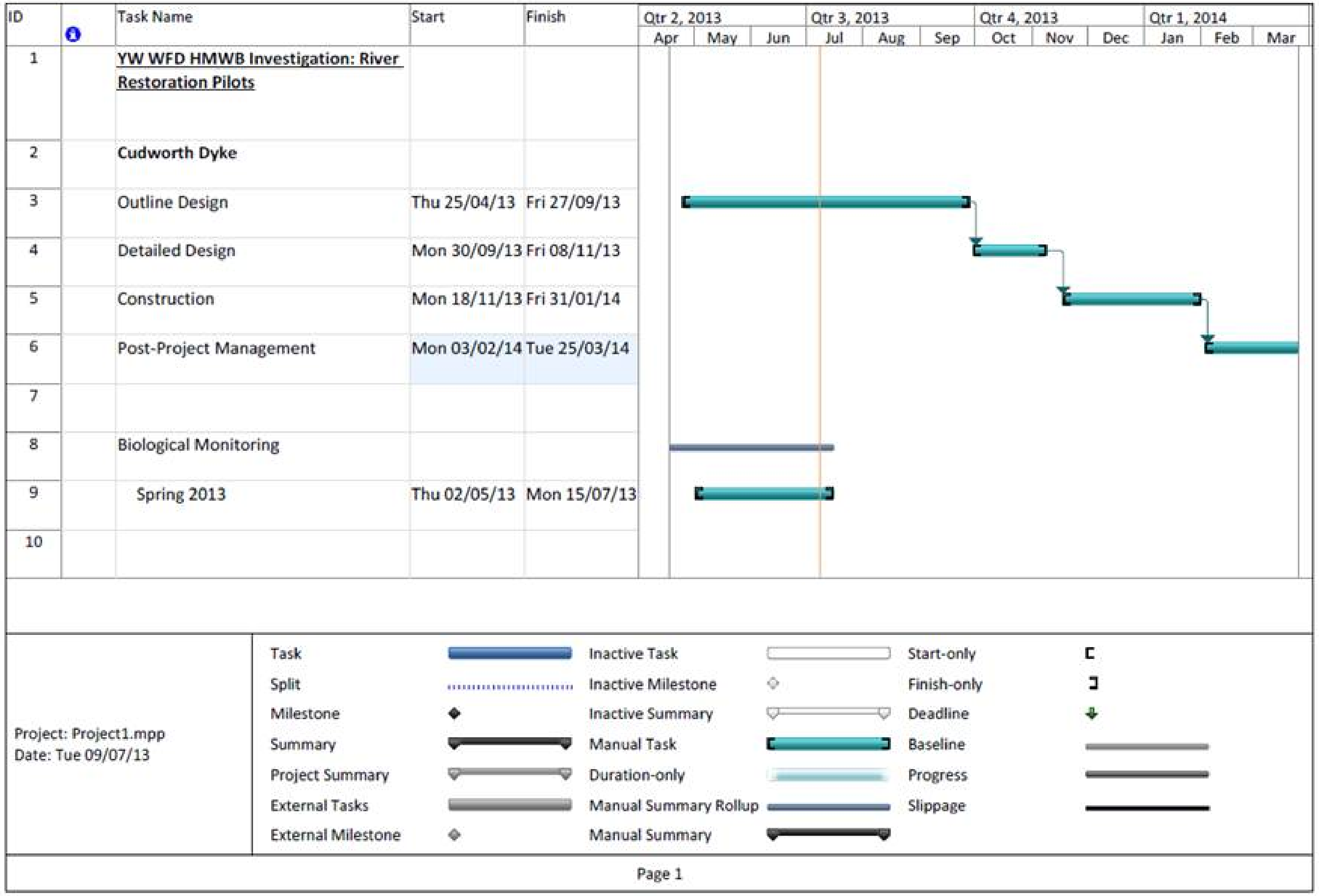
- Some options (e.g. reed beds) may require maintenance;
- Invasive species have been recorded in this reach;
- Presence of water voles must be taken into consideration, although restoration is likely to improve their habitat;
- Location and potential influence of disused landfill site around Pools Ings area needs to be clarified;
- Potential contamination of sediments;
- Investigation of upstream sediment sources will be necessary;
- High iron concentration found upstream of the reach, currently being investigated by EA;
- The risk of destructive use of the area by quad bikers must be taken into consideration by including deterrent design options in restoration proposals;
- Potential for future impact from HS2 route.

5.4 Timescales

The following tasks need to be conducted in order to further develop and implement the options presented for the restoration of Sandybridge Dyke:

- Outline Design- including project planning, GI support guidelines, ECI, optioneering, environmental survey(s), etc.;
- Detailed Design and Ground Investigations;
- Construction;
- Post-Project Management; and

Ecological monitoring- Baseline ecological monitoring of macroinvertebrates and macrophytes was conducted during the Autumn season and being now conducted for the Spring season.



ID	Task Name	Start	Finish
1	**YW WFD HMWB Investigation: River Restoration Pilots**		
2	**Cudworth Dyke**		
3	Outline Design	Thu 25/04/13	Fri 27/09/13
4	Detailed Design	Mon 30/09/13	Fri 08/11/13
5	Construction	Mon 18/11/13	Fri 31/01/14
6	Post-Project Management	Mon 03/02/14	Tue 25/03/14
7			
8	Biological Monitoring		
9	Spring 2013	Thu 02/05/13	Mon 15/07/13
10			

Figure 14 Expected programme of works for 2013

5.5 Considerations and Risks/Constraints

The following key considerations and risks have been identified in relation to the proposed river restoration works at the site. These issues will need to be considered and reviewed during the subsequent stage of the project.

- Terrestrial ecology constraints, such as protected and invasive species;
- Upstream and downstream flood risk implications as a result of the proposed river restoration works;
- Water and sediment quality constraints; it will be necessary to investigate potential contamination of sediments accumulated on the river bed, relating to former land uses in the area;
- Upstream sediment sources. Impact of erosion/runoff from former mining areas and farmland upstream needs to be investigated.
- Impact of extreme flood events on the restored channel. What can be allowed to occur naturally and what can be managed needs to be determined;
- Presence of invasive species and protected species;
- Location and condition of former landfill site to assess whether it may impact the restoration project.

6 Further Work Requirements

It is recommended that the following components of work should be undertaken for the site during the next stage of the Sandybridge dyke reach one project:

- Continued stakeholder engagement – discussion with Groundwork of proposed restoration options, and key constraints and opportunities to be able to maximise the benefits of interventions;
- Development of an outline design for the proposed river restoration options to be taken up by YW;
- Maintenance/update monitoring plans outlining the requirements and scope of further macroinvertebrate and macrophytes monitoring, in order to adequately assess the baseline biological status of the waterbody within the study area and to ensure a standard of repeatability to monitor success in the future;
- Implementation of a pre-construction biological monitoring programme;
- Land ownership negotiations if necessary (to be led by YWS).
- Topographical (channel cross-sectional and floodplain) survey requirements;
- Ground investigations and utilities investigations;
- Hydraulic investigations;
- Flood Risk Assessment;
- Planning Application requirements (including ecological and river works consent licenses);
- Pre-construction ecological surveys.

Appendix A

WFD Assessment

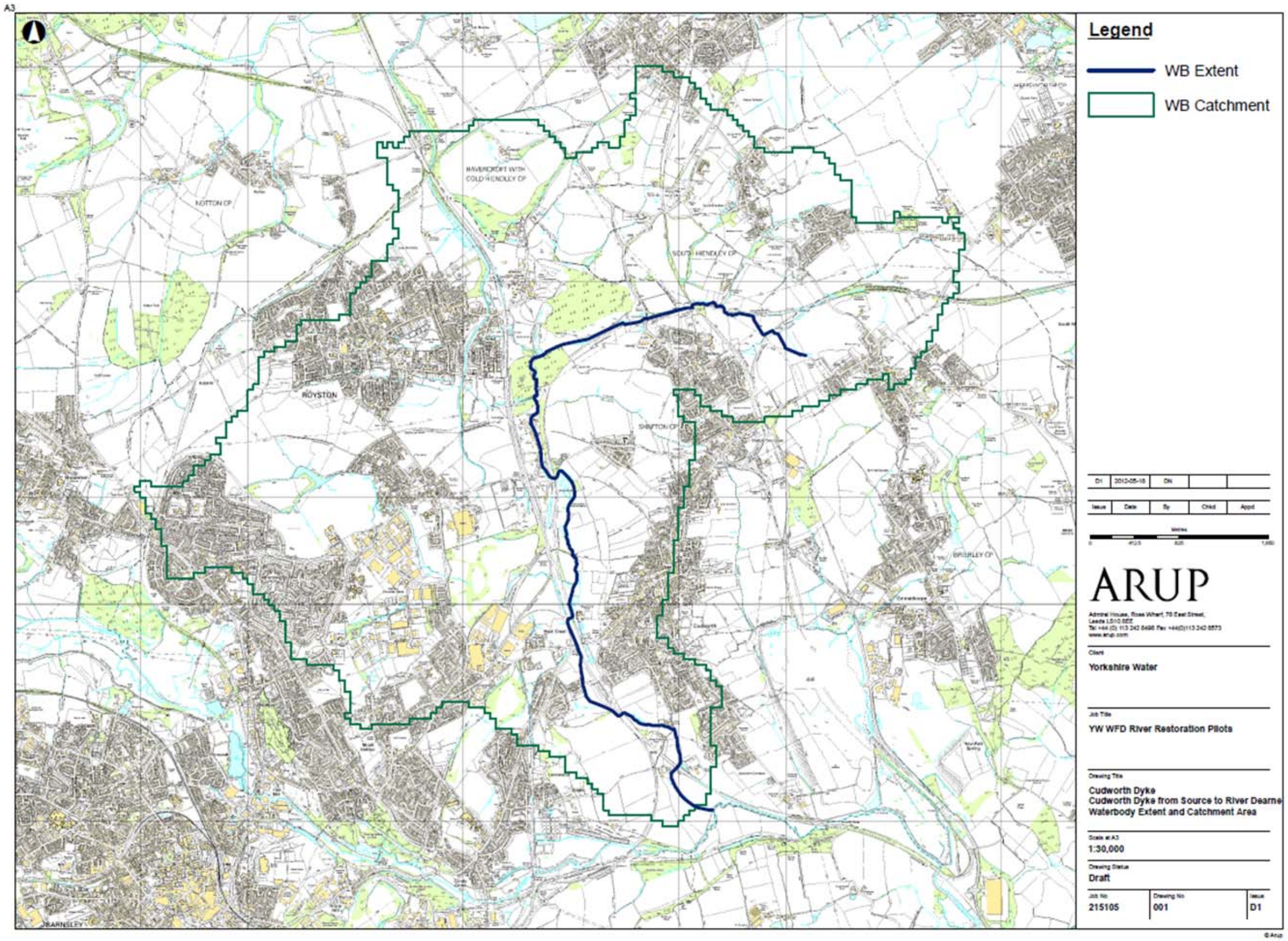
Contents

A1 Waterbody status

Quality Elements	2009/10 Status	2011 Status
Biological Status:		
Macroinvertebrates	Bad	Moderate
Phytobenthos	No Assessed	Moderate
Physic-Chemical Status:		
Ammonia	Bad	Bad
Dissolved Oxygen	Poor	Poor
pH	High	High
Phosphate		Moderate
Temperature	High	High
Hydromorphological Status:		
Hydrology	Good	Good
Morphology	Good	Good
Specific Pollutants:		
Copper	High	High
Zinc	High	High

High [blue]	
Good [green]	**Target Status (2027)**
Moderate [yellow]	**Current Status (2011)**
Poor [orange]	
Bad [red]	**Previous Status (2009/10)**

A2 Waterbody extent



Map 1 Waterbody map

A3 EA Monitoring

A3.1 Macroinvertebrates

Environment Agency (EA) macroinvertebrate monitoring data is available for a range of different dates and locations along Cudworth Dyke (see **Table 2** below). Over different timescales, the EA has conducted macroinvertebrate sampling at eight separate sites along the waterbody (although not all of them at the same times): Sandybridge Lane, downstream of Sandybridge, downstream of Coking Works, downstream of Rabbit Ings, Pools Ings, Boulder Bridge, downstream of Cudworth STW and downstream of Cudworth Carrs Lane.

Table 1: EA macroinvertebrate survey sites and dates along Cudworth Dyke (EA, 2012)

Site Name	Site ID	Site Location	Sample Dates	Sample IDs
SANDYBRIDGE LANE	1254	SE3870011600	1992 (May); 1992 (Sept);	6296 3346
D/S SANDYBRIDGE LANE	75964	SE3867011650	1999 (May); 1999 (Nov);	313347 313365
D/S COKING WORKS	984	SE3780011200	1991 (July); 1992 (May); 1992 (Sept)	13058 6324 3348
AT BOULDER BRIDGE	1437	SE3760010600	1995 (May); 1995 (Sept); 2000 (May); 2000 (Oct)	8654 10661 308137 316768
D/S RABBIT INGS (MIXING ZONE)	75965	SE3767011290	1999 (May); 1999 (Nov)	313359 313373
POOL INGS (VISABLE LIMIT)	75966	SE3763011200	1999 (May); 1999 (Nov)	313363 313396
D/S CUDWORTH CARRS LANE	91	SE3890007900	1990 (June); 1990 (Sept); 1991 (April)	11276 5068 6532
D/S CUDWORTH STW	1251	SE3897207514	1992 (May); 1992 (Sept); 1995 (May); 1995 (Sept); 2000 (May); 2000 (Oct); 2002 (May); 2002 (Oct); 2003 (May); (2003 (Sept); 2004 (April); 2004 (Oct); 2007 (April);	1996 2063 8655 896 308140 316763 344236 348417 358750 365032 379507 385310 551925

			2007 (Oct); 2010 (May); 2010 (Sept); 2012 (April)	557733 608178 613205 636107

However, data has been utilised from only one of the above sites as part of the EA WFD macroinvertebrate monitoring ("D/S Cudworth STW", Site ID 1251). This site is located downstream of the Cudworth waste water treatment works (WwTW) (SE3897207514), towards the downstream end of Cudworth Dyke prior to the confluence with the River Dearne. Macroinvertebrate samples have been collected and analysed from this site in spring/autumn 2007, spring/autumn 2010, and spring 2012. It is believed that an autumn 2012 sample has also been taken at this site, but is yet to be processed.

The results indices derived from this data are provided in **Table 3** below. These results indicate a water quality pressure but no issue in relation to the river flow regime.

Table 2: Results indices derived from sample data previously collected at the EA Macroinvertebrate sample site near the Cudworth WwTW (SE3897207514)

Indices	Spring 2007	Autumn 2007	Spring 2010	Autumn 2010	Spring 2012
BWMP	18	44	46	99	59
APST	2.57	3.38	3.54	4.5	3.93
LIFE	4.8	6.36	6.55	6.2	6.31

Legend:

- ***BMWP*** *– Biological Monitoring Working Party (Combined BMWP score of all species recorded (indices reflecting water quality tolerance within species water quality indicator. High scores reflect dominance of species that 'cleaner' water quality conditions)*
- ***ASPT*** *– Average score per taxon (BMWP/N_TAXA)*
- ***LIFE*** *–Lotic Invertebrate Index for Flow Evaluation (indices reflecting flow tolerance within species). High scores reflect dominance of species that tolerate or seek high flow conditions*

A3.2 Other Biological Quality Elements

No EA macrophyte or fish WFD monitoring has been undertaken along the waterbody to date. Limited EA diatom WFD monitoring has taken place downstream of Cudworth SWT works (at the same site as the macroinvertebrate monitoring described above). Diatom samples have been collected and analysed from this site in spring/autumn 2010 only. The results derived from this survey data have been utilised to classify the current Phytobenthos WFD status for the waterbody as Moderate.

A3.3 Water Quality

EA water quality monitoring has been carried out at five sites along the waterbody: downstream of Royston CSO, downstream of Pools Lane CSO, Boulder Bridge, downstream of Ryder & Green and Wood Nook Farm.

YW has also undertaken a detailed, continuous water quality monitoring study has for the catchment in relation to compliance of their CSO, WwTW, and pumping station assets[1].

[1] Yorkshire Water (2012), B4548 UPM Studies – Grimethorpe & Royston, Cause & Effect Report (report prepared by MWH)

A4 Reasons for failure

The following table (table 1) was created by the Environment Agency as part of the River Basin Management Plan*.

Table 3 Reason for Failure (EA, 2011)

Element	Pressure	Tier_1 Reason For Failure (Water Management Issue)	Tier_1 Certainty	Tier_2 Reason for Failure (Activity / Source)	Tier_2 Certainty	Tier_3 Reasons for Failure (Sector)	Tier_3 Certainty	Magnitude of pressure
Ammonia (Annex 8)	Unknown	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Ammonia (Annex 8)	Unknown	point source	Probable	sewage discharge (intermittent)	Probable	Water industry	Probable	major
Ammonia (Phys-Chem)	Unknown	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Ammonia (Phys-Chem)	Unknown	point source	Probable	sewage discharge (intermittent)	Probable	Water industry	Probable	major
Dissolved Oxygen		point source	Probable	sewage discharge (intermittent)	Probable	Water industry	Probable	major
Dissolved Oxygen	Unknown	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Invertebrates	BOD	point source	Confirmed	sewage discharge (intermittent)	Confirmed	Water industry	Confirmed	major
Invertebrates	Dissolved Oxygen	diffuse source	Suspected	contaminated land	Suspected	urban	Suspected	minor
Invertebrates	Morphology	physical modification	Confirmed	urbanisation - urban development infrastructure	Confirmed	Urban and transport	Confirmed	minor
Invertebrates	Ammonia	diffuse source	Suspected	contaminated land	Suspected	urban	Suspected	minor

Invertebrates	Ammonia	point source	Confirmed	sewage discharge (intermittent)	confirmed	water industry	confirmed	major
Invertebrates	BOD	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Invertebrates	Phosphate	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Invertebrates	Dissolved Oxygen	point source	confirmed	sewage discharge (intermittent)	confirmed	water industry	confirmed	major
Invertebrates	Phosphate	point source	Confirmed	sewage discharge (intermittent)	Confirmed	water industry	Confirmed	major
Invertebrates	Sediment	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	major
Invertebrates	Sediment	diffuse source	confirmed	drainage - mixed	Confirmed	Urban	confirmed	minor
Invertebrates	Other	diffuse source	Confirmed	Contaminated water body bed sediments	Confirmed	Industry	Confirmed	minor
Invertebrates	Dissolved Oxygen	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Invertebrates	Ammonia	diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Invertebrates	BOD	point source	Confirmed	industrial discharge (EPR)	Confirmed	Industry	Confirmed	minor
Invertebrates	Morphology	physical modification	Confirmed	flood protection - structures	Confirmed	Urban and transport	Confirmed	minor
Phosphate		diffuse source	Confirmed	trading/industrial estates	Confirmed	Industry	Confirmed	minor
Phosphate	Unknown	point source	Probable	sewage discharge (intermittent)	Probable	Water industry	Probable	major

*YW's UPM Study (2013) concludes that YW assets along this stretch of watercourse are compliant with their consents and YW is currently awaiting approval from the EA.

Appendix B

List of Stakeholders

B1 Cudworth Dyke Stakeholders

Organisation	Representative(s)
Environment Agency	Anthony Downing anthony.downing@environment-agency.gov.uk
Barnley Metropolitan Borough Council	Derek Bell (Highways and Engineering) derekbell@barnley.gov.uk Russ Boland (Countryside & Park Officer) RussellBoland@barnsley.gov.uk (also FoCM) Trevor Mayne (Countryside Officer) trevormayne@barnsley.gov.uk
Dearne Valley NIA RSPB	Pete Wall pete.wall@rspb.org.uk
Yorkshire Wildlife Trust	Tom Hayek tom.hayek@ywt.org.uk Carys Hutton carys.hutton@ywt.org
Don Catchment Rivers Trust	Karen Eynon karen.eynon@dcrt.org.uk Chris Firth chris.firth@dcrt.org.uk John Housham john.housham@dcrt.org.uk
Friends of Carlton Marsh	Cliff Gorman cliff1947@hotmail.com
Groundwork Dearne Valley	Mick Brikinshaw Mick.Birkinshaw@groundwork.org.uk
Scrapyard Representative	Peter Hadfield
IDB	Alison Briggs alison.briggs@shiregroup-idbs.gov.uk

Appendix C

Assessment of Historical Change

Contents

C1 Land-Use Change

C1.1 Summary of historical land-use change

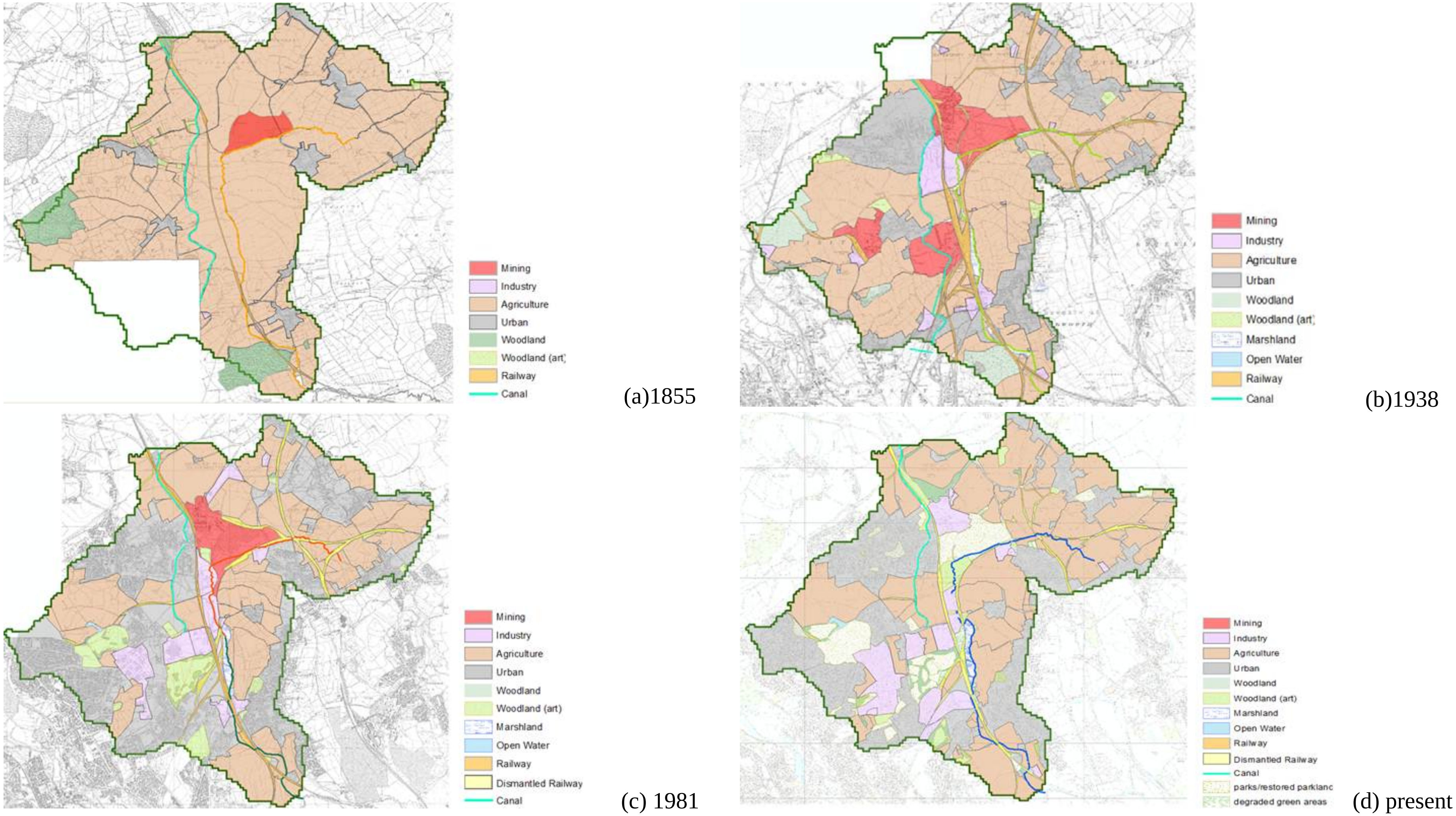


Figure 1 Evolution of land use since 1855 in the Cudworth Dyke catchment

Key changes identified since 1855

The following key changes have been identified, listed below from upstream to downstream:

- Small quarries and colliery sites at Sandy Bridge and South Hiendley to north east;
- Development of Monokton Main Colliery and Rabbit Ings tip;
- Development and expansion of BHWR, MCB and DVJ railway network (localised channel culverting and realignment at crossing points);
- Development of Sewage Works (including offline reservoir and pump house infrastructure) at Lund Hill, Pools Ings, and Sandy Bridge;
- Expansion of Shafton to south of Sandy Bridge;
- Dismantlement of railway network, and removal of sections at Rabbit Ings and Pool Ings;
- Restoration of Rabbit Ings tip;
- Removal of Sewage Works infrastructure at Pools Ings;
- Development and expansion of BHWR and LMS railway network immediately west and east of channel (including offshoots and engine sheds at Boulder Bridge) (localised channel culverting and realignment at crossing point);
- Development of Carlton Main Colliery immediately to south west;
- Development of Sewage Works immediately to south west;
- Residential development along Royston Road to north east of Carlton Marsh;
- Appearance of marshy ground around Carlton Marsh;
- Dismantlement of BHWR and LMS railway network immediately west and east of channel (including offshoots and engine sheds at Boulder Bridge);
- Development at Boulder Bridge (scrap yards) and channel culverting;
- Development immediately south of Shaw Lane and channel culverting;
- Establishment of Carlton Marsh Nature Reserve, creation of ponds/scrapes and diversion of channel course;

C1.2 Changes in mining and industrial use

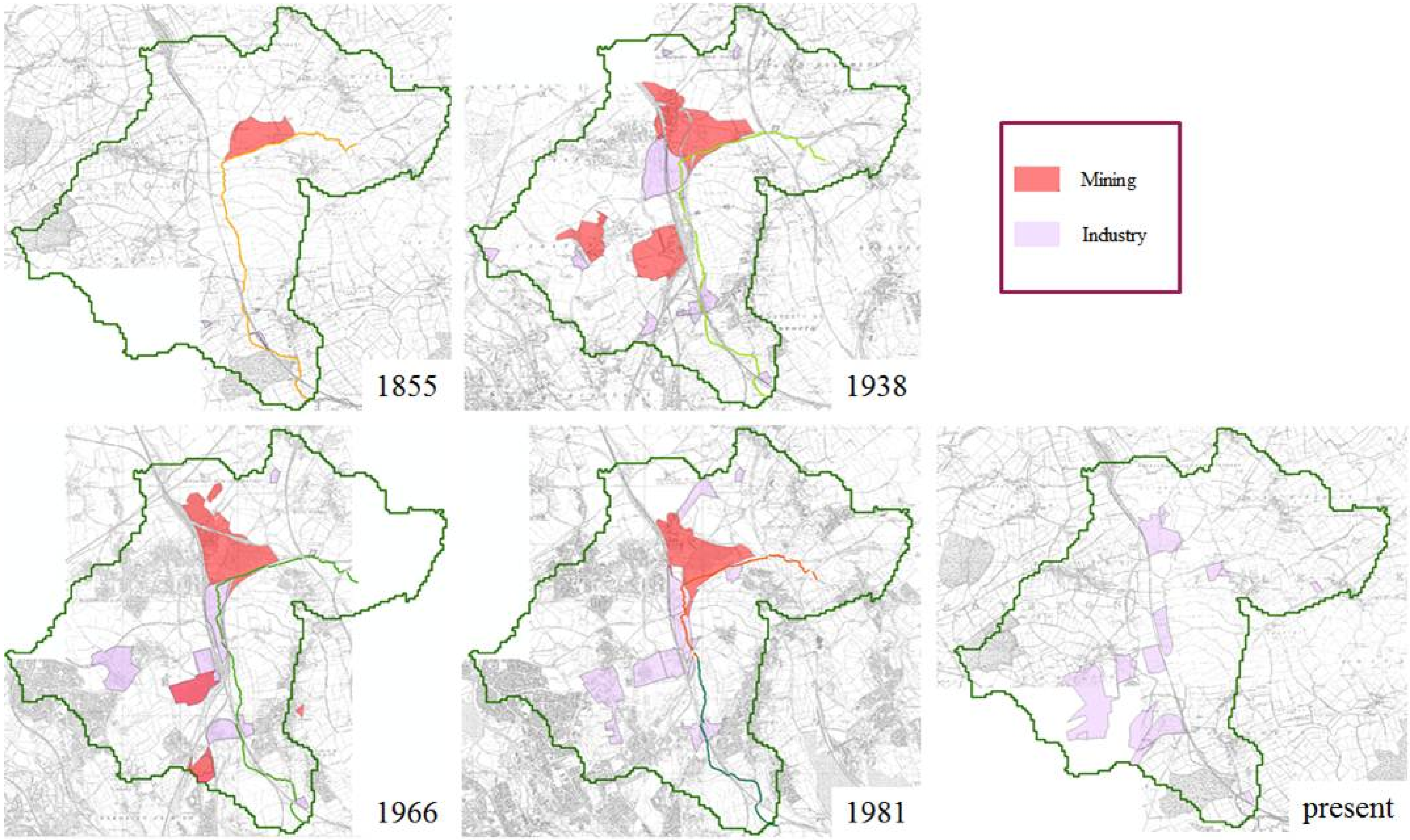


Figure 2 Evolution of extent of land used for mining and industrial activities

C1.3 Changes in rural and urban land

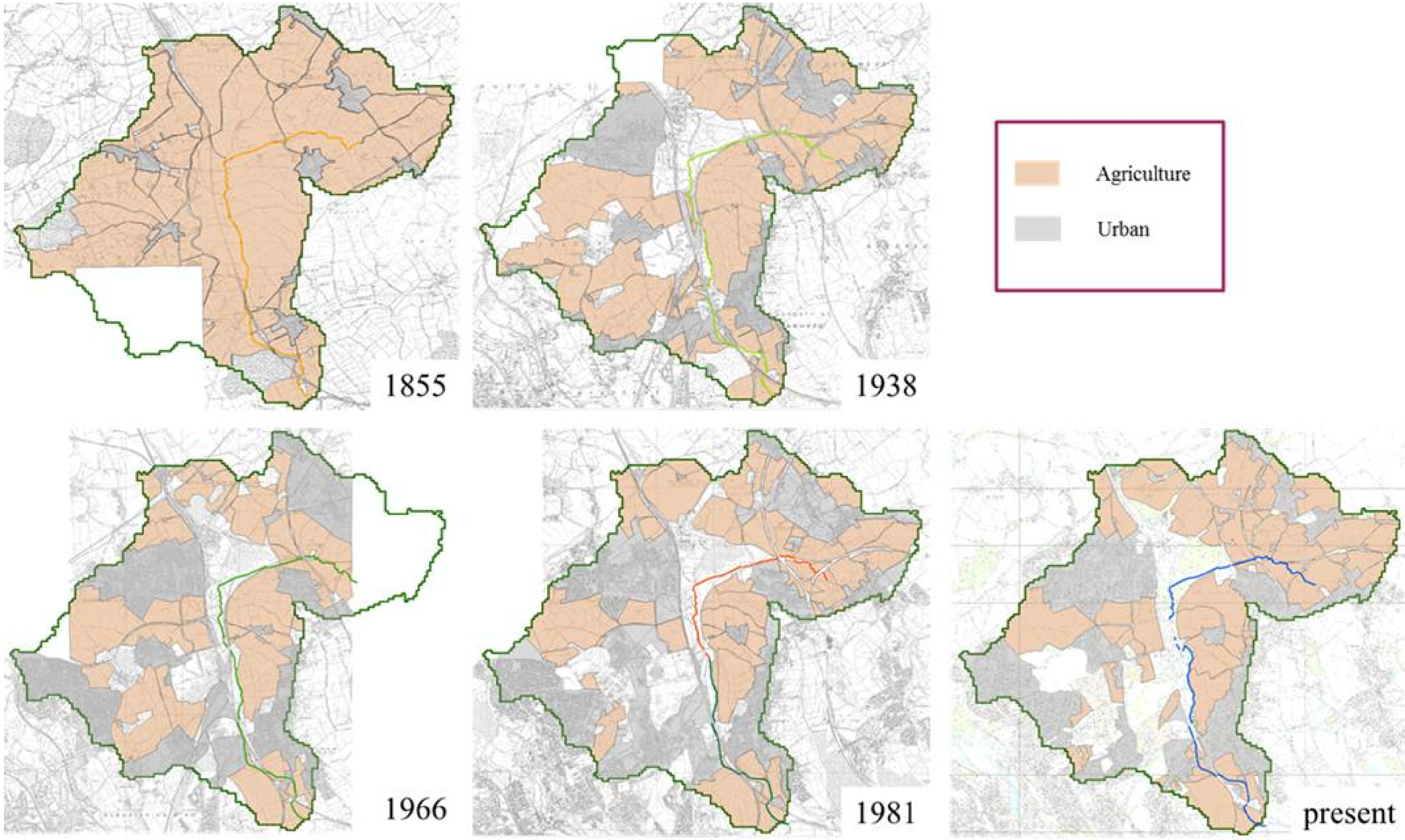


Figure 3 Evolution of extent of farmland and urban areas

C1.4 Evolution of Green Areas

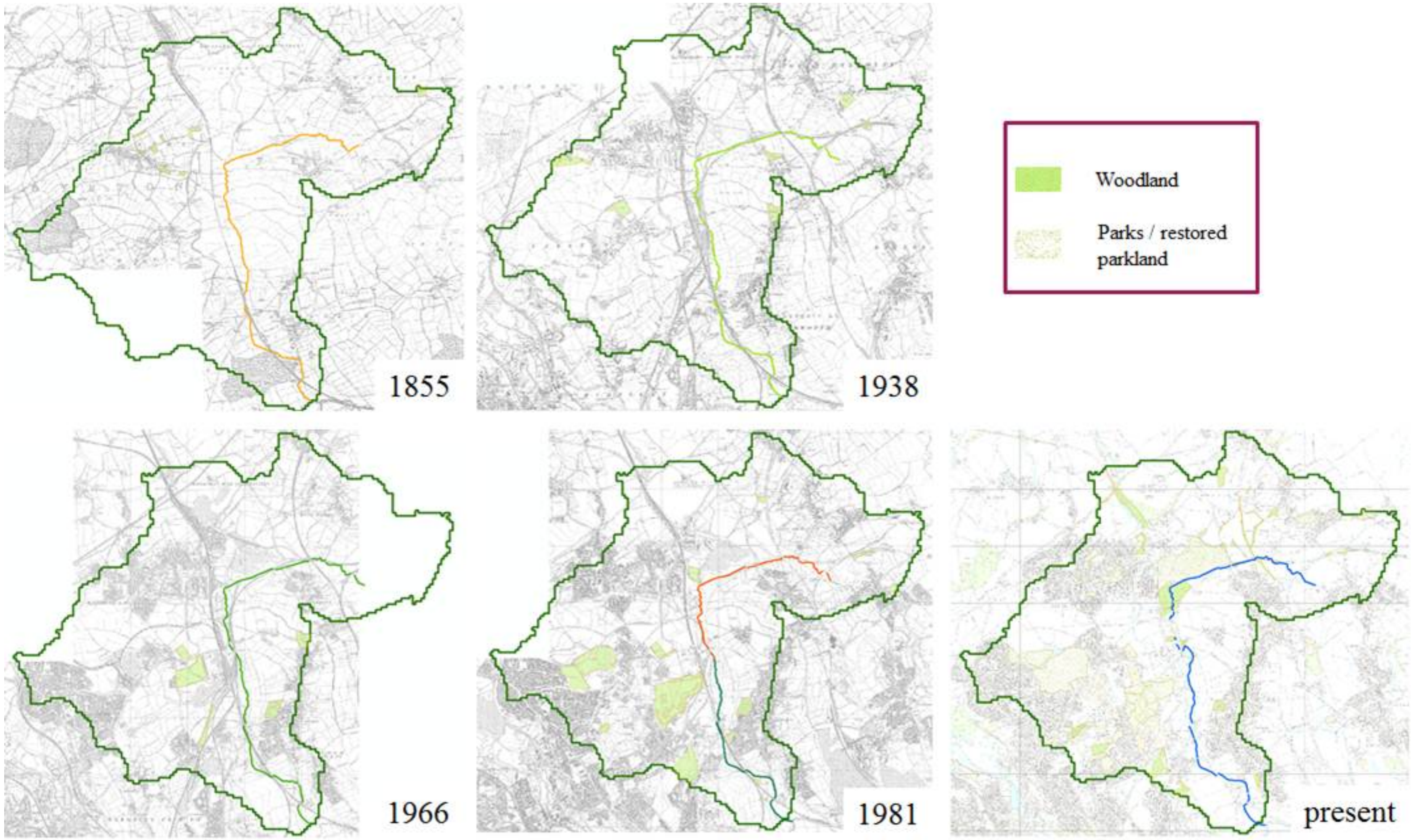


Figure 4 Evolution of woodland and parkland in the Cudworth Dyke Catchment

C2 Channel change

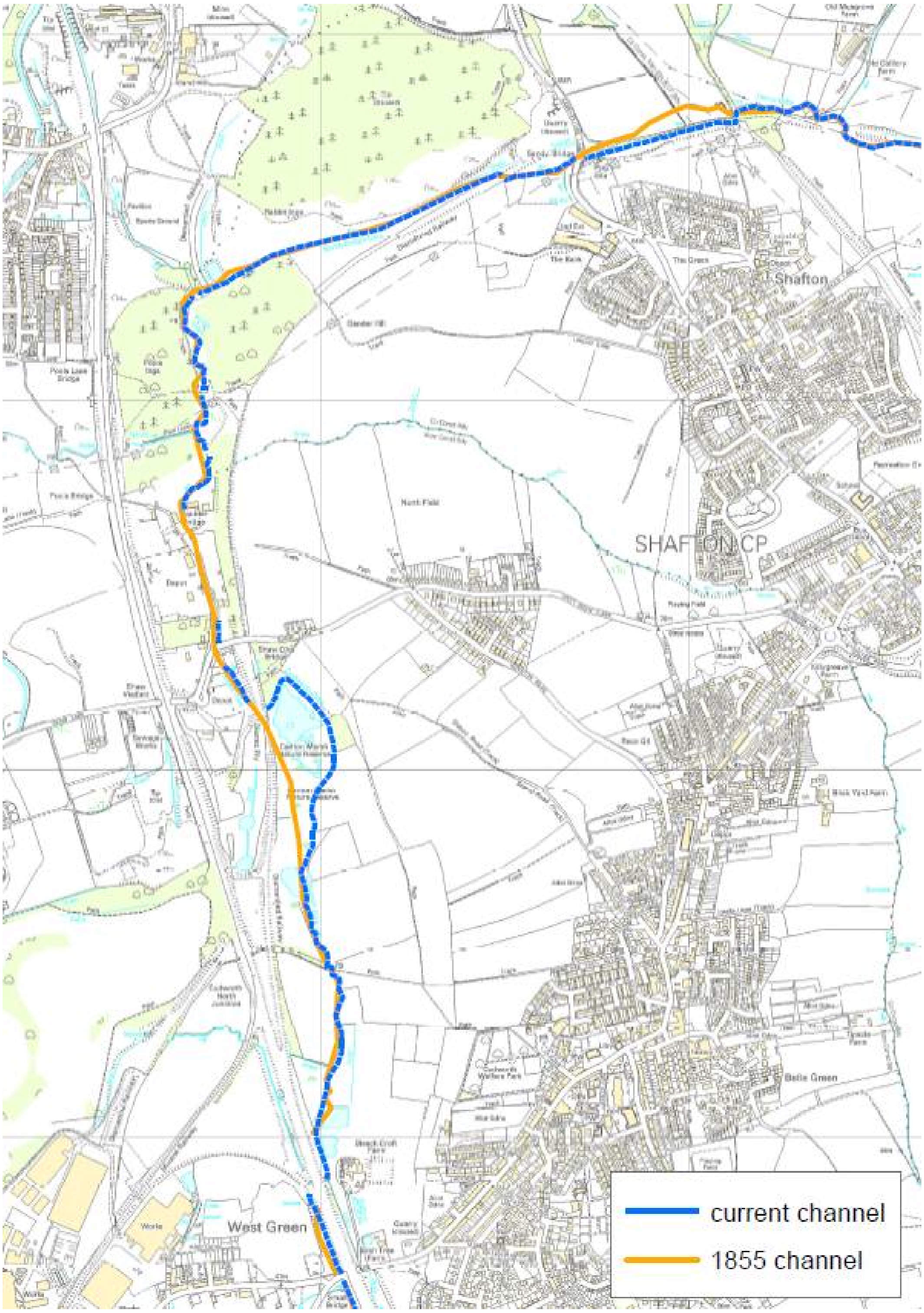


Figure 5 Comparison of 1855 channel and current channel

Appendix D

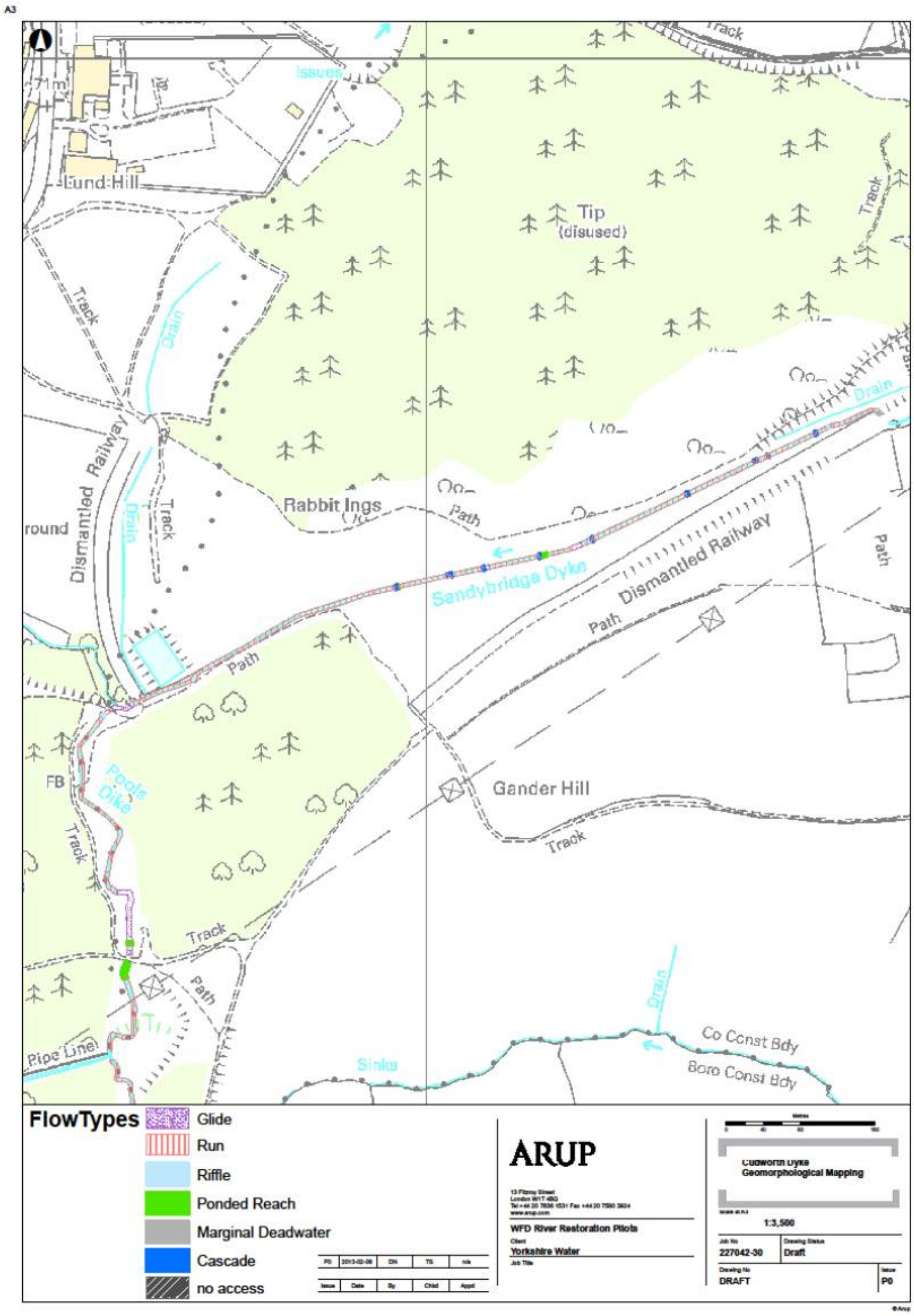
Geomorphological Mapping

Contents

The main geomorphological characteristics were recorded during the site visit. Examples of mapped flow types and in-channel structures are presented below. GIS data of recorded information are provided separately.

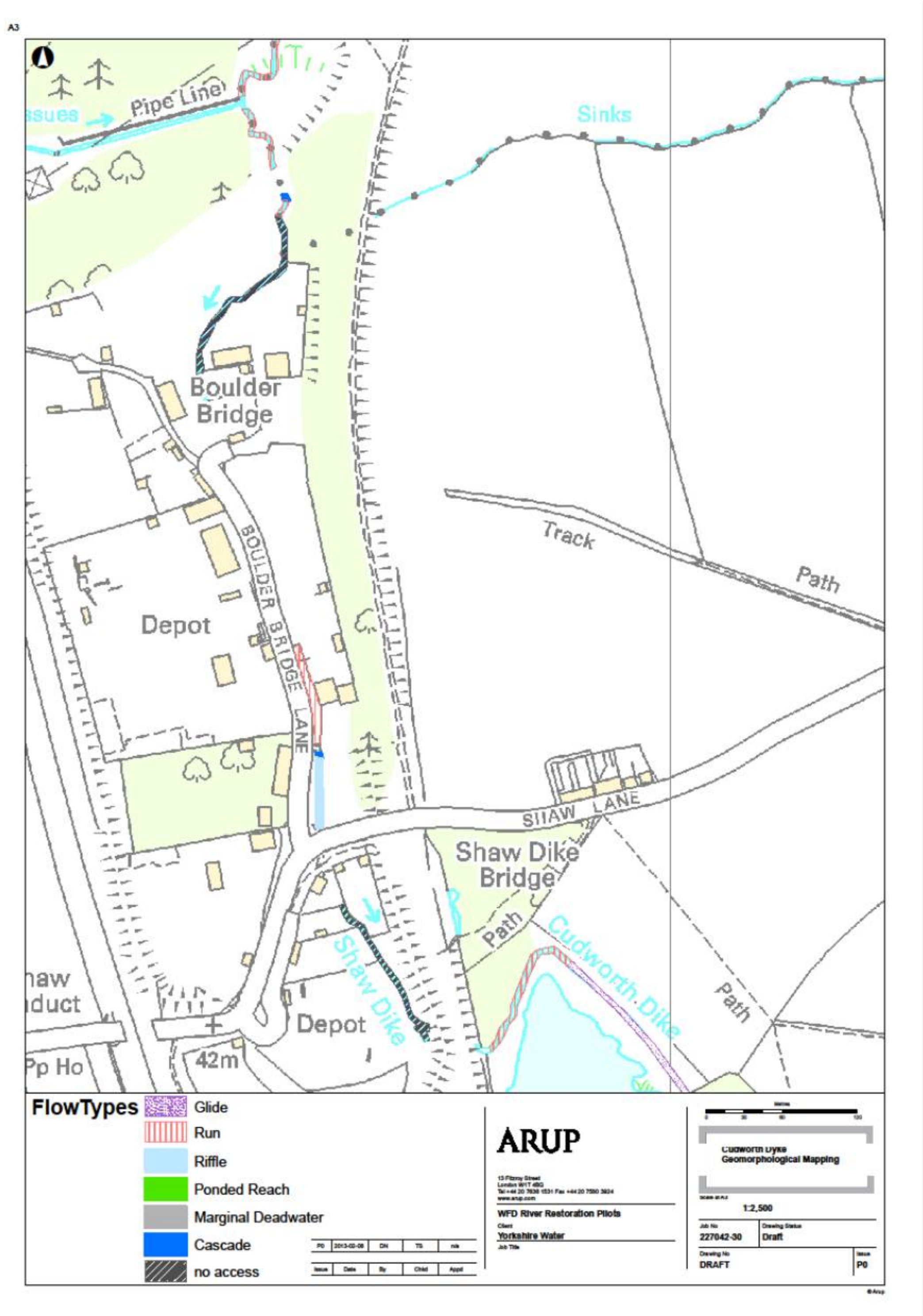
D1 Flow types

D1.1 Sandybridge Dyke and Pools Dyke



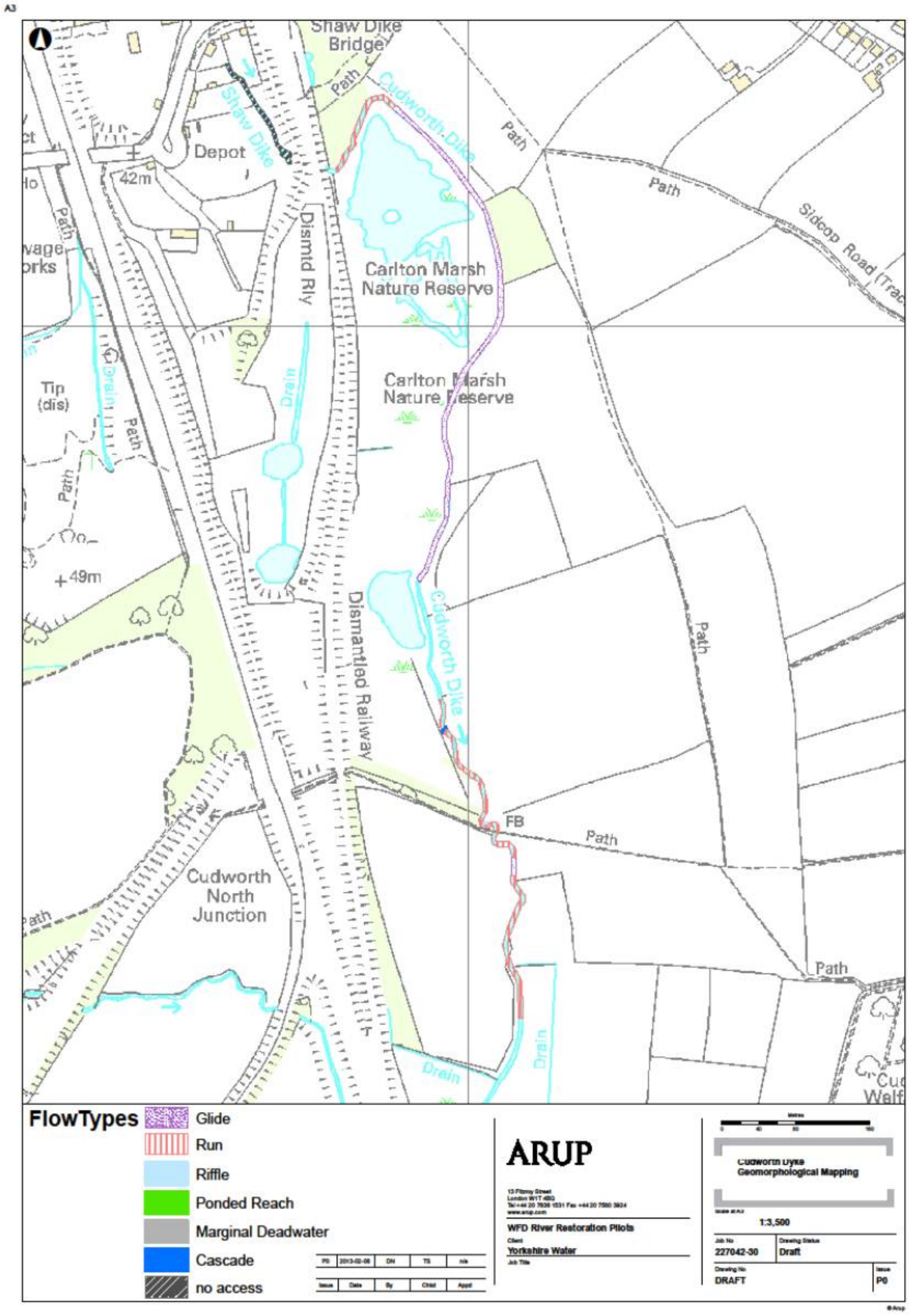
Map 1 Flow types observed during site walkovers in the upper reaches of the study area.

D1.2 Pools Lane CSO and Boulder Bridge



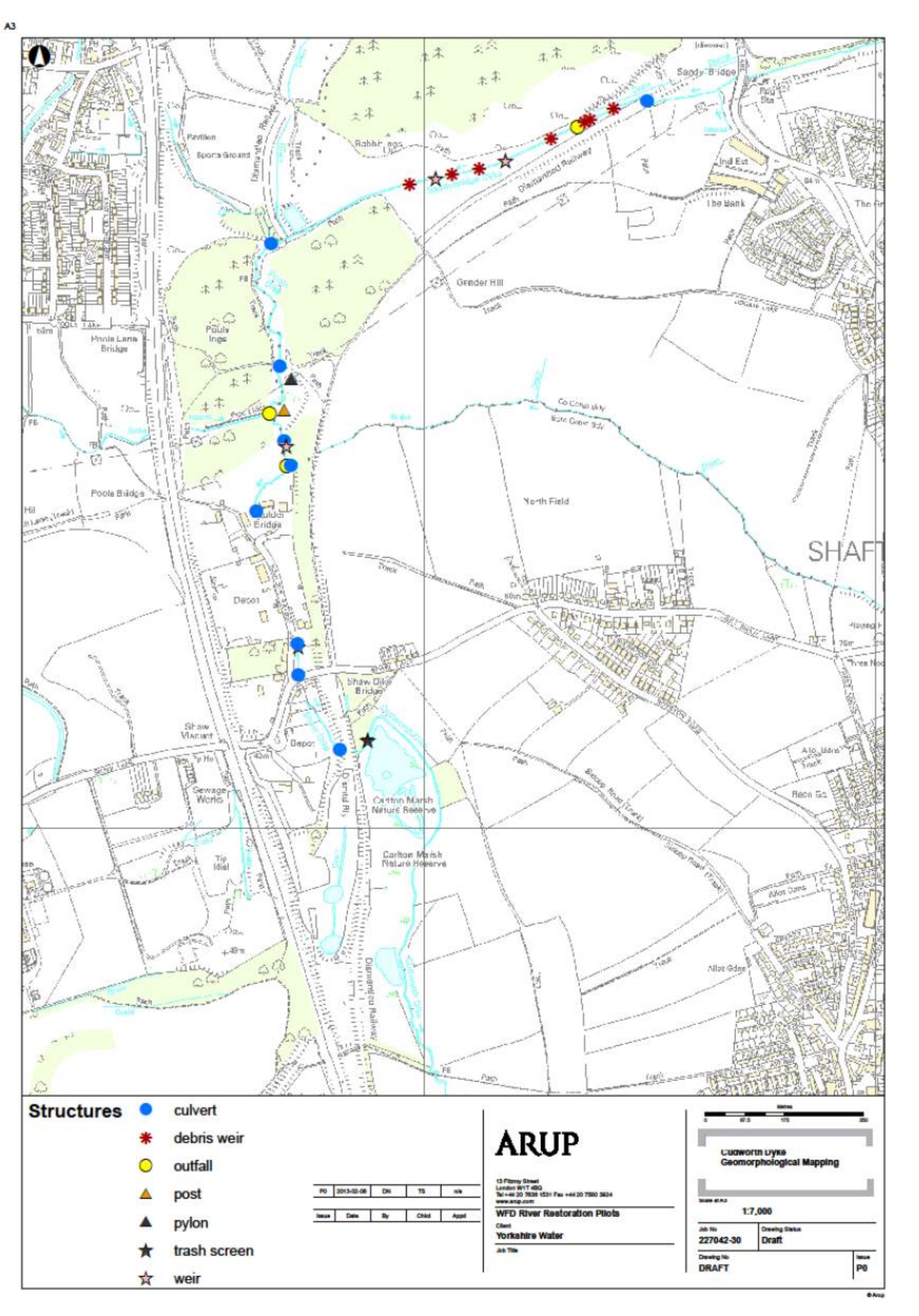
Map 2 Flow types observed in reaches 3 and 4

D1.3 Carlton Marsh and downstream of Carlton Marsh



Map 3 Flow types observed in the downstream section of the study area

D2 Structures



Map 4 In-channel structures recorded in the study area

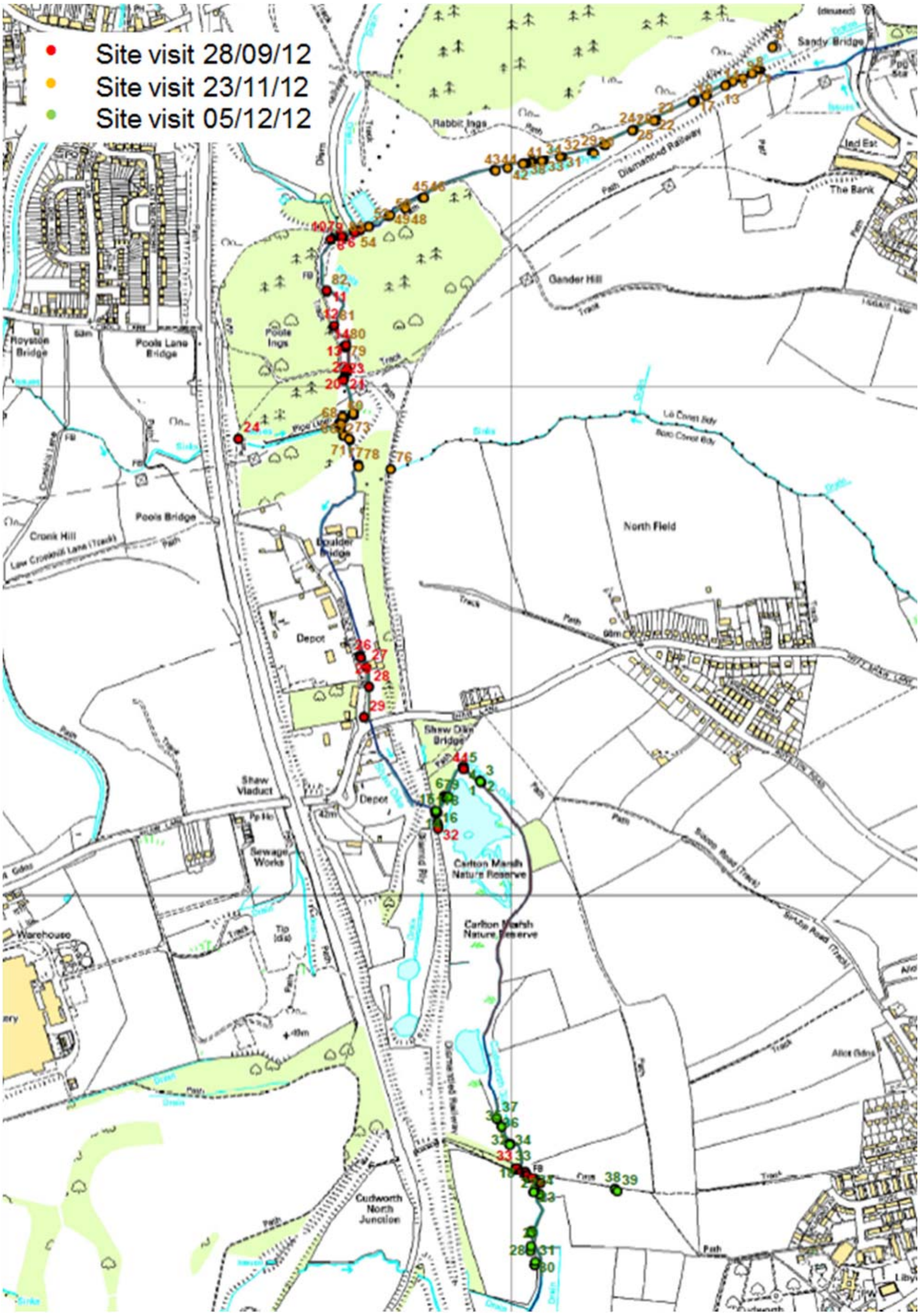
Appendix E

Site Photographs

Contents

E1 Photograph locations

All photographs are provided separately at a higher resolution



Map 1 Map showing locations of photographs taken during walkovers.

E2 Reach 1: Sandybridge Dyke

E2.1 Walkover day 1 (28/09/12)




E2.2 Walkover day 2 (23/11/12)










































E3 Reach 2: Pools Dyke

E3.1 Walkover Day 1 (28/09/12)














E3.2 Walkover day 2 (23/11/12)









E4 Reach 3: Pools Lane CSO

E4.1 Walkover day 2 (23/11/12)

















E5 Reach 4: Boulder Bridge

E5.1 Walkover day 1 (28/09/12)

E5.2 Walkover day 2 (23/11/12)

 (tributary from Shafton)

E6 Reach 5: Carlton Marsh

E6.1 Walkover day 1 (28/09/12)






E6.2 Walkover day 3 (5/12/12)











E7 Reach 6: Downstream of Carlton Marsh

E7.1 Walkover day 1 (28/09/12)



E7.2 Walkover day 3 (5/12/12)



















Appendix F

List of Data Provided by Stakeholders

F1 List of Data

Table 1 Data provided by third parties*

Document/data	**Provided by**	**Date**
Lidar data (DTM)	A. Downing (EA)	15/01/2013
Channel Activities and land ownership information filled on map at workshop	Stakeholders	19/10/2012
Cudworth Dyke NIA photographs (.jpg)	P. Wall (RSPB)	19/10/2012
Map of DVGH NIA extent (pdf) and shapefile (shp)	P. Wall (RSPB)	22/11/2012
DVGH NIA Eco-Vision (hard copy)	P. Wall (RSPB)	19/10/2012
Carlton Marsh breach photographs and breach location map (jpg and pdf)	R. Boland (BMBC)	22/10/2012 02/01/2013
Carlton Marsh proposal	FoCM (C. Gorman)	22/10/2012
Cudworth Dyke Development minutes	R. Boland (BMBC)	22/10/2012
Water voles at Carlton Marsh report (docx) and location map of water vole rafts (pdf)	C. Hutton (YWT)	19/10/2012
Ecology data and sediment sources (writing on map, now digitised)	C. Hutton (YWT)	19/10/2012
Land owner permission map for water vole surveys (pdf)	C. Hutton (YWT)	30/10/2012
Rabbit Ings BMBC Ownership Map (bmp)	D. Bell (BMBC)	29/04/2013

* Data in digital format

Appendix G

Catchment Restoration Plan

Contents

G1 Catchment Plan

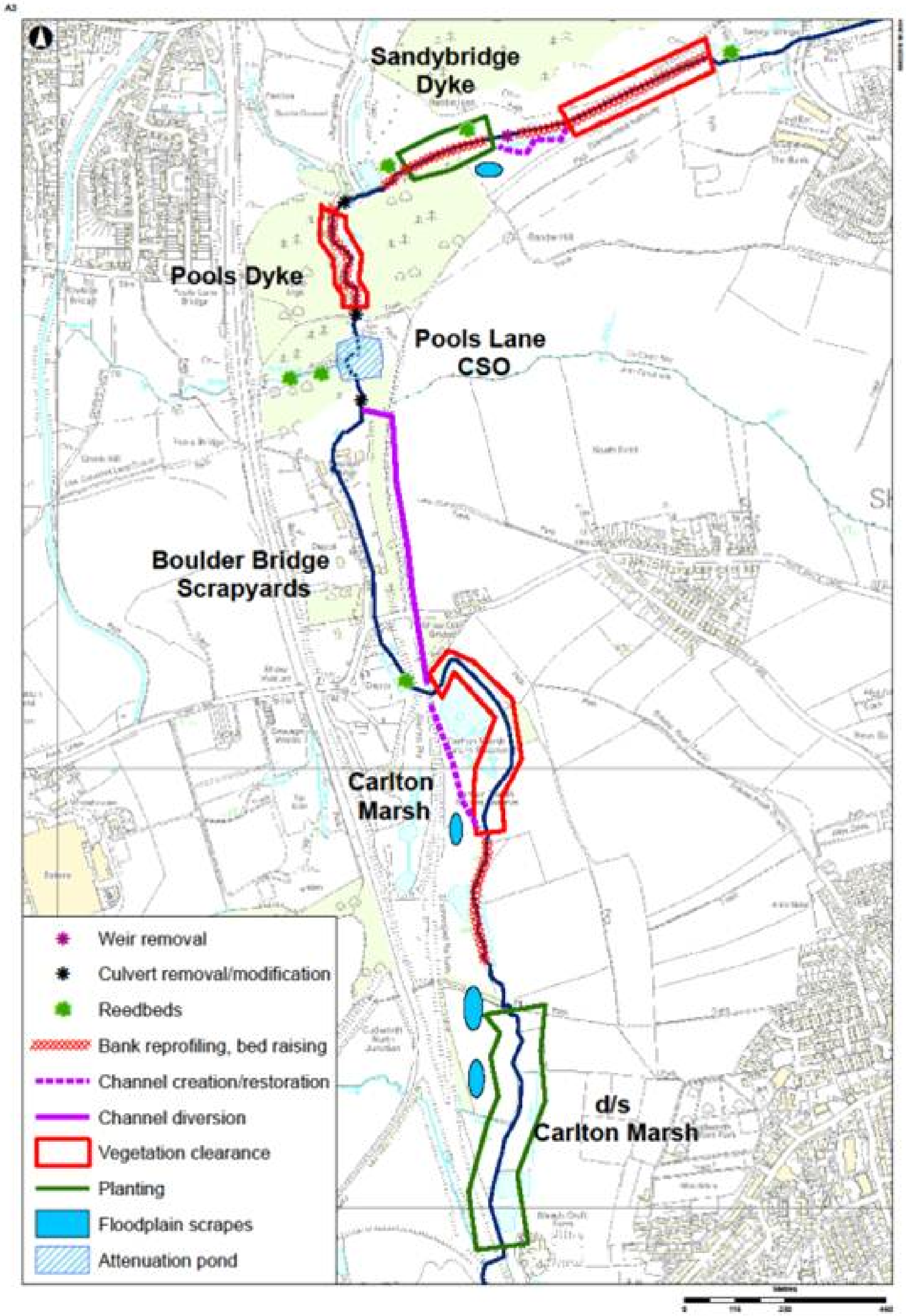
A restoration plan has been designed for Cudworth Dyke (Map 1), based on the existing issues identified in the catchment and considering discussion with stakeholders. A phased restoration approach was suggested, starting at Sandybridge Dyke in Phase 1 and moving downstream afterwards.

Yorkshire Water will concentrate its efforts on the restoration of Sandybridge Dyke in Phase 1, while stakeholder coordination will continue to discuss the requirements and devise a strategy for the subsequent phases.

Further information on specific restoration techniques can be found, among others, at the River Restoration Manual[1] and the STREAM River Restoration Advice Note[2]).

[1] STREAM River Restoration Techniques Advice Note, Shttp://webarchive.nationalarchives.gov.uk/20101118120645/http:/www.streamlife.org.uk/resources/publications/

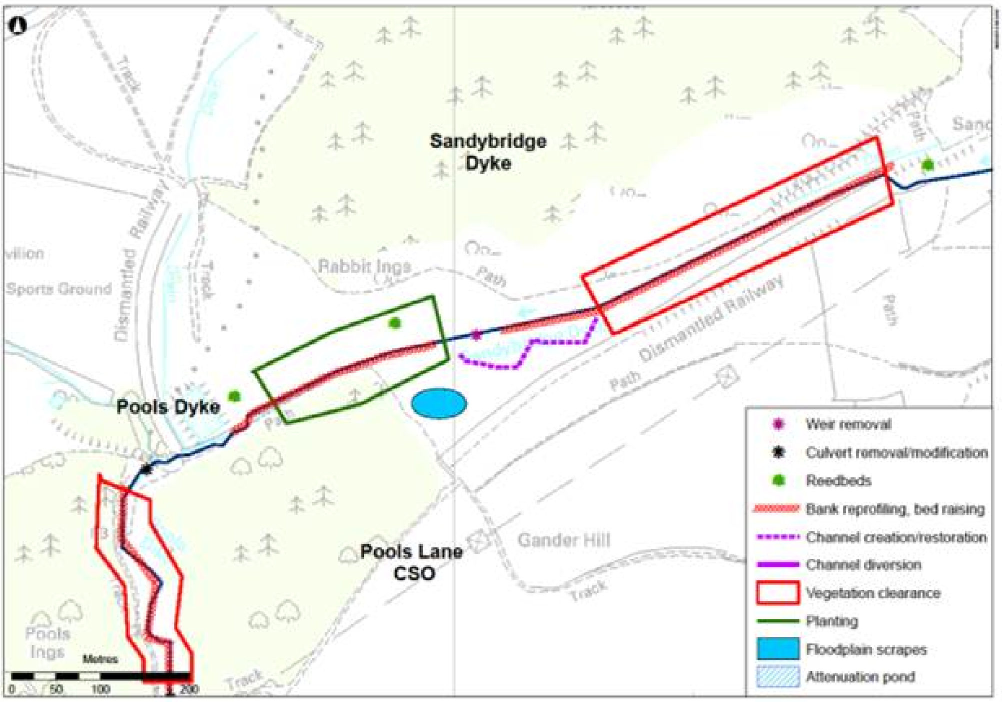
[2] River Restoration Manual, RRC, http://www.therrc.co.uk/rrc_manual.php



Map 1 Sketch catchment restoration plan for Cudworth Dyke

G2 Reach 1: Sandybridge Dyke

The plan for this reach (Map 2) is presented in detail in section 5.3.1 of the main report.



Map 2 Sketch restoration plan for Sandybridge Dyke

G3 Reach 2: Pools Dyke

Several potential **restoration options** have been identified for the Pools Dyke area (Map 3 Sketch restoration plan for Pools DykeMap 3), including:

Vegetation Management:

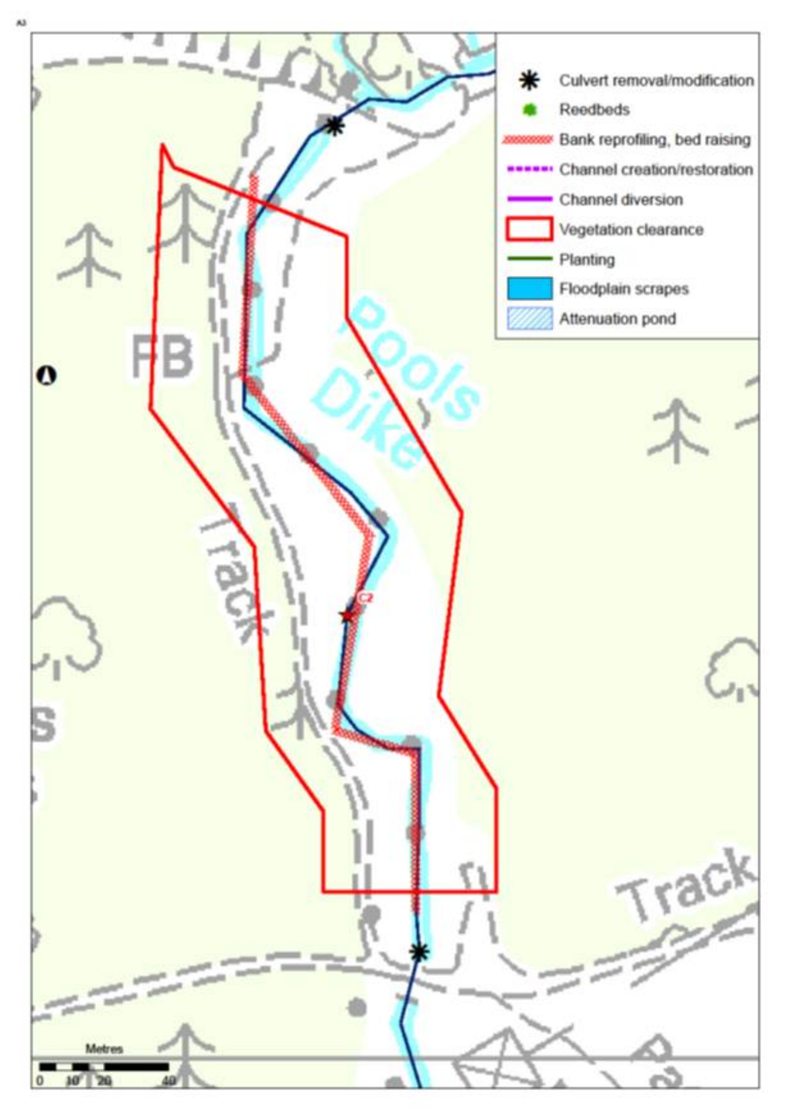
- Selective clearance of in-channel trees and dense riparian vegetation (particularly along upstream end of reach);

Culvert removal / replacement:

- There is potential to remove or replace the existing culverts in order to increase flow velocity, improve sediment connectivity and fish passage and reduce siltation;

Localised **bank re-profiling** and **bed raising** could have a variety of benefits, such as:

- Increased morphological variability and connectivity of the channel;
- Reduced bank erosion and channel incision;
- Feasibility of silt removal or stabilisation should be investigated



Map 3 Sketch restoration plan for Pools Dyke

Key **constraints** for reach 2:

- Existing access tracks, footpaths and culverts;
- Existing utilities;
- Pylons at downstream end of reach;
- Topography of floodplain;
- Water voles at upstream end;
- Dense vegetation (clearance required for access);
- Potential location of former tip.

The Pools Dyke reach offers some key **opportunities**:

- At least partly public land (BMBC)
- Undeveloped / little used area- potential to enhance / regenerate whole area (substantial scheme but potentially significant environmental, community and amenity benefits)

G4 Reach 3: Pools Lane CSO

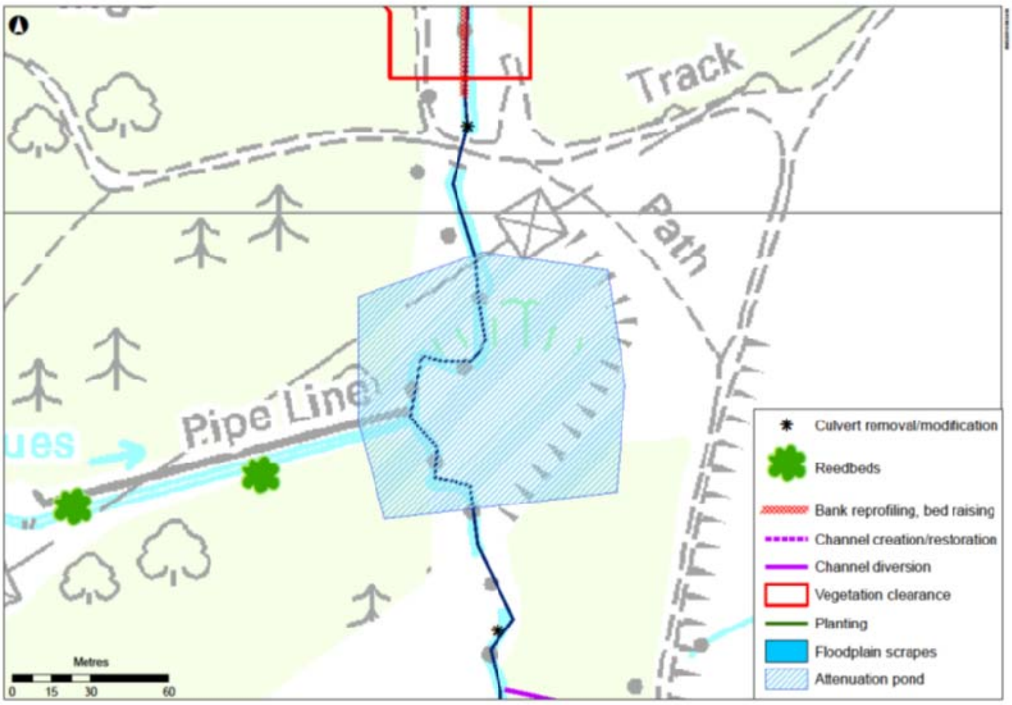
The following **restoration options** have been identified for the Pools Lane CSO reach (Map 4):

Creation of **attenuation pond** with controlled outflow, which would address a series of issues:

- Localised silt trap;
- Wetland habitat enhancement and amenity improvement;
- Potential for flood storage;
- May require maintenance

Creation of a series of **reed beds** along the route and at outlet of the CSO and canal overflow tributary, with the benefits listed below. There is also potential for **removal of the CSO pipeline** / hard standing and create a series of **settling lagoons** alongside reed beds:

- Filter inflows from CSO, surface runoff and associated urban pollutants;
- Localised silt trap;
- Habitat enhancement;
- May require periodic maintenance



Map 4 Sketch restoration plan for the Pools Lane CSO reach

Key **constraints** for this reach:

- Land ownership and access (unknown at this stage);
- Existing utilities (CSO);
- Pylons and telegraph lines/poles;

Key **opportunities**:

- Flat floodplain topography providing a ‘natural’ basin;
- Undeveloped / little used area- potential to enhance / regenerate whole area.

G5 Reach 4: Boulder Bridge

The main **options** identified for the Boulder Bridge reach (Map 5) are:

Channel diversion around scrap yards along eastern side of railway embankment:

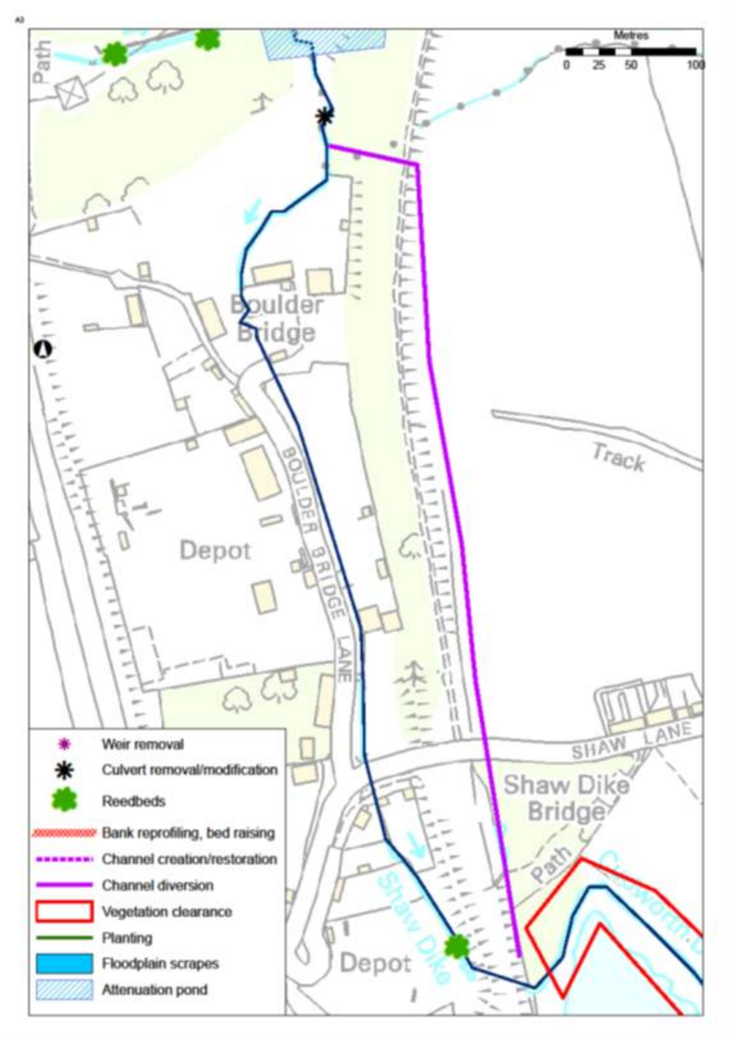
- This option would require tunnelling/opening railway embankment and new culvert beneath Shaw Lane Road;
- The diverted channel could tie in to existing Carlton Marsh diversion or restored channel route (depending on downstream reach options);
- The existing channel through scrap yards could be isolated (develop into SUD system);
- Alternatively, diversion could happen along western side of railway embankment.

Creation of a **reed bed system** downstream of scrap yards:

- This system would filter river and surface runoff inflows and associated urban pollutants from scrap yards;
- The isolated channel could function as a localised silt trap;
- There is potential for habitat enhancement;
- The reed beds may require periodic maintenance.

Partial or total **removal of culvert** at upstream end of reach:

- This would provide improved sediment connectivity and fish passage;
- Flow dynamics would also be improved.



Map 5 Sketch restoration plan for Boulder Bridge

Key **constraints**:

- Land ownership and access. Difficult access upstream due to tree cover and railway embankment along left bank. Access through scrap yards may be required;
- Spatial constraints due to the presence of existing developments and embankments;
- Telegraph lines/poles;
- Existing culvert at upstream end of reach (before channel enters the scrap yard area);
- Existing culverts under scrap yards and under Shaw Lane at downstream end of reach.

Key **opportunities**:

- Potential for SUDs pilot through scrap yards;
- Interest shown by some scrap yard operators.

G6 Reach 5: Carlton Marsh Nature Reserve

Several **options** have been identified for the Carlton Marsh reach (Map 6), including:

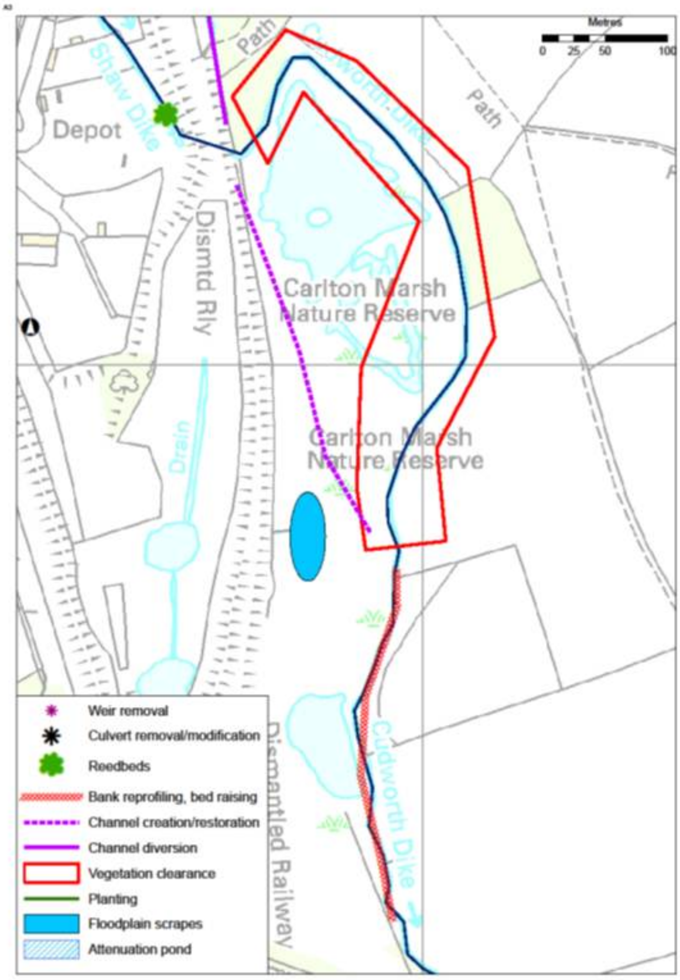
Restoration of historic channel route alongside eastern side of railway embankment:

- Due to the existing pollution issues, this option could initially include embankment of the left bank to prevent connectivity with ponds/scrapes. Significant improvement of water quality would be require before channel can be connected to existing wetland
- Overflow into existing diverted channel could be retained as pond / backwater habitat, where existing silt deposits could be isolated;
- Reconnect with existing channel at downstream end of nature reserve;
- This option could be used to control exiting flooding pressure;

Wetland enhancement, which would provide:

- Increased scrape area;
- Improved structure of upstream/downstream wetland connection.
- Vegetation control:
- Excavation of willows that are currently encroaching on the wetland;
- Vegetation clearance along diverted channel banks.

Alternatively in-channel enhancements could be implemented, but these would be pricey and less effecting in addressing existing channel issues.



Map 6 Sketch restoration plan for Carlton Marsh Nature Reserve

Key **constraints**:

- Poor access due to dense vegetation and wet marshy ground;
- Difficult ground conditions for construction;
- Existing Nature Reserve pond and scrapes, which are water level and water quality sensitive;
- Existing railway embankment along right floodplain.

Key **opportunities**:

- Land ownership- council owned land;
- Active stakeholders;
- Potential for multiple benefits, such as channel restoration, flood alleviation, habitat enhancements, improvement of amenity value, etc.

G7 Reach 6: Downstream of Carlton Marsh

The options identified for the reach located downstream of Carlton Marsh Nature reserve (Map 7) are listed below:

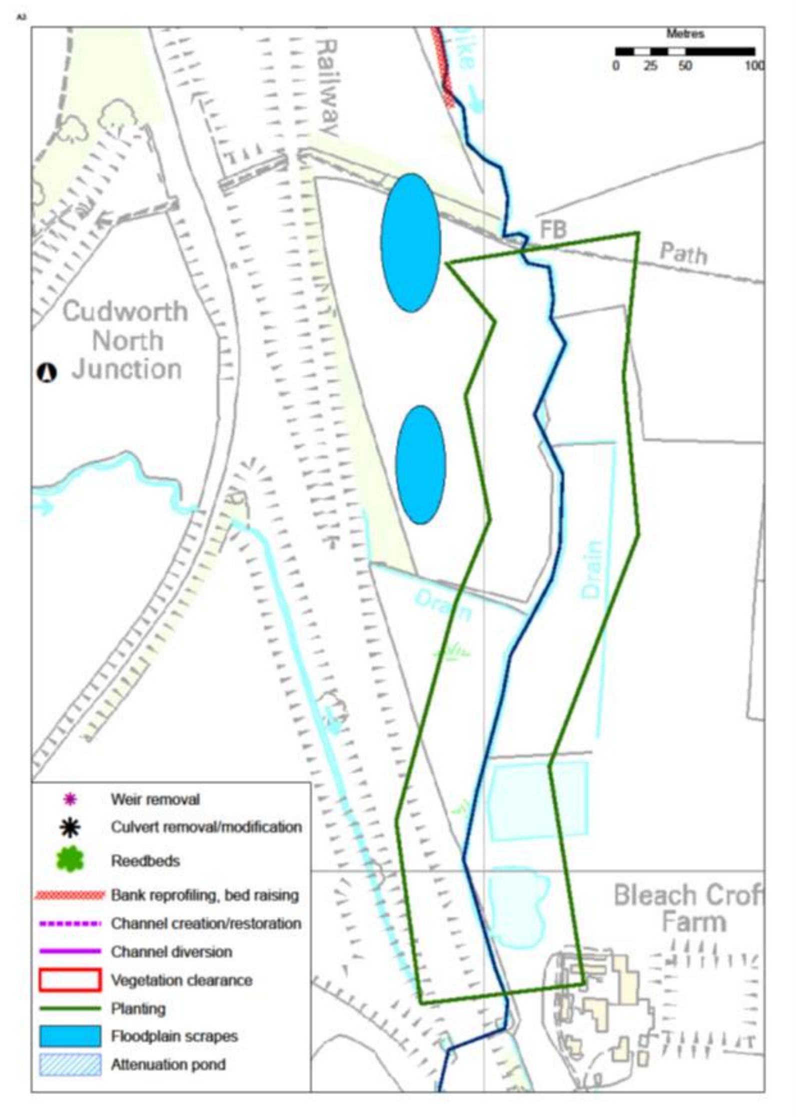
Tree and riparian **vegetation planting** along downstream end of reach:

- Provision of areas of overhanging vegetation, channel cover, shading, etc.;
- This option would contribute to reduce poaching and direct surface runoff and associated fine sediment delivery.

Extension of floodplain scrapes along right floodplain:

- Floodplain rehabilitation;
- BAP wetland habitat creation (floodplain grazing marsh);
- This option could act as a buffer for surface water runoff and provide flood water storage.

Potential for localised **in-channel works**.



Map 7 Sketch restoration plan for the reach downstream of Carlton Marsh

Key **constraints**:

- Land ownership and land use (left bank)- privately owned agricultural land (arable and grazing);
- Construction access- dense tree cover upstream, suitability of existing access tracks and river crossing needs to be investigated;
- Presence of water voles;
- Existing rail embankment, culvert and ponds at downstream end of reach.

Key **opportunities**:

- Land ownership and land use (right bank)- council owned land, rough grazing;
- Existing floodplain scrapes along right floodplain (council aspirations to extend these);
- Potential to integrate improved diffuse pollution/sediment management;
- Potential to integrate flood storage features.

Appendix H

YW assets in Cudworth Dyke

H1 YWS Assets

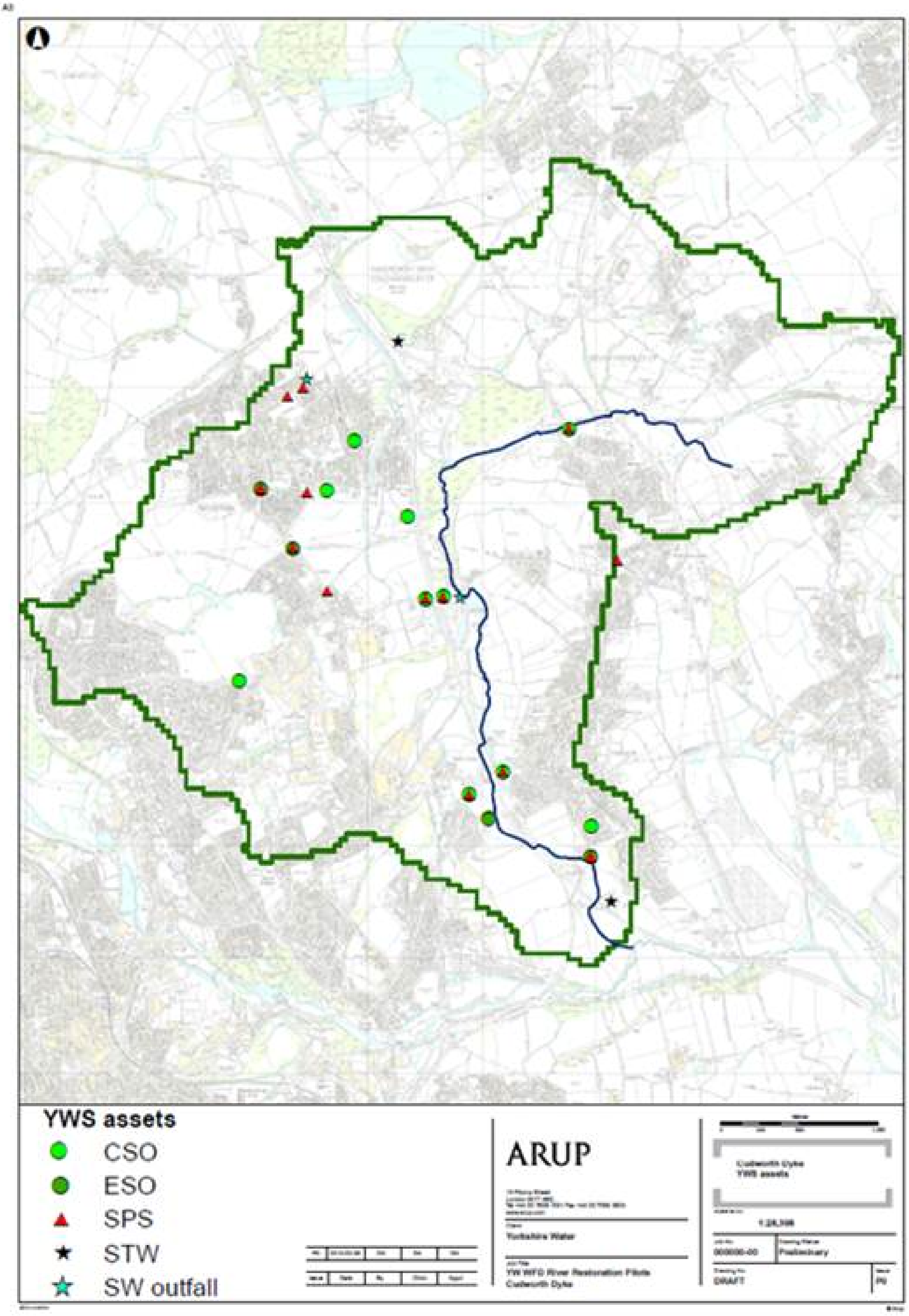


Figure 1 Location Map of YWS assets.

Appendix I

Baseline Monitoring Plan Draft

Contents

Full results and interpretation will be available in a separate report when baseline monitoring works are complete. Spring data from the targeted monitoring works around Sandybridge Dyke (Spring & Autumn 2013) are currently being compiled and assessed.

I1 Introduction

I1.1 Study Background and Aims

Yorkshire Water (YW) is funded in AMP5 to investigate compliance of its infrastructure assets with the Good Ecological Potential (GEP) objectives of Heavily Modified Water Bodies (HMWBs), as defined within the UK River Basin Management Plans (RBMPs) under the EU Water Framework Directive (WFD). The overall investigation will establish the technical feasibility, effectiveness, and costs and benefits of a range of potential solutions relating to the generic Mitigation Measures derived by the Environment Agency (EA) for HMWBs.

As part of this wider investigation, YW has commissioned Arup to implement and assess a distinct, water-quality driven river restoration pilot scheme on the Cudworth Dyke watercourse, located to the north-east of Barnsley, West Yorkshire. The scheme is being designed to utilise river restoration measures to mitigate existing water quality and hydromorphological pressures identified within the Cudworth Dyke catchment. The scheme aims to assess the feasibility, and cost-effectiveness of implementing a range of river restoration techniques as a means of enhancing local water quality conditions and contributing towards the improvement of Biological and Physic-chemical Quality Elements; and thus the overall Ecological Status of waterbodies, as classified under the WFD.

I1.2 Baseline Biological Monitoring

A baseline biological monitoring programme has been developed as part of the YW river restoration scheme at Cudworth Dyke. This has been designed to provide a robust assessment of the baseline biological status of the watercourse at the identified restoration reach (as best as possible within the study timescales). This baseline information will provide a better understanding of the existing condition and potential cause of failures at the site and will in turn inform the design of relevant river restoration works to address the hydromorphological and physic-chemical water quality impacts. The baseline will provide the basis for the appraisal of the effectiveness (benefits) of the restoration works in contributing towards improvements in Ecological Status.

The components of the baseline biological monitoring programme have been focused in-line with the key Biological Quality Elements included in the waterbodies' GES assessments. Of these, macrophytes and macroinvertebrates have been included within the monitoring programme. Fish have not been included following initial survey attempts at the site (partly due to the lack of fish recorded at the site, and partly due to the practicalities of undertaking electro-fishing surveys relating to accessibility, high amounts of in-channel silts causing health and safety issues, and high levels of water conductivity encountered at the site). Diatoms have not been included also, as they only offer limited interpretation of change.

All monitoring has been planned and undertaken in a manner which will allow comparison against EA WFD monitoring and classification procedures; thereby assisting in interpretation of change (allowing policy level as well as biological change to be noted).

I1.3 BACI Approach

As an overarching structure to the ecological monitoring, sites have been selected using the Before After Control Impact (BACI) approach. This method allows measurement of the potential impact of a change by measuring conditions prior to restoration then comparing the results from conditions post restoration. Both control and impact watercourses are used to allow comparison of drivers thereby assisting in interpretation of the impact of restoration against wider variables.

It should be noted that whilst, the BACI approach strengthens conclusions as to causal mechanisms of change, it cannot prove that restoration has caused any observed changes, unless it is possible to rule out all other factors that may be driving change.

I1.4 Scope of Report

This report outlines the baseline biological monitoring programme that has been developed for the YW WFD river restoration pilot scheme at Cudworth Dyke described above. It details the biological components and environmental variables captured by the monitoring works, the field and analytical methods applied, and the locations, type and frequency of field surveys undertaken.

Assessment results and interpretation derived from the various components of seasonal monitoring surveys are summarised in the Appendices. All raw baseline biological monitoring datasets are provided separately in excel format.

A summary of the elements outlined within the following sections of the report is provided below:

- Site location information for the Cudworth Dyke river restoration site (with reference to the accompanying baseline assessment and optioneering report);
- Methodology applied for the field surveying of each component of the baseline biological monitoring programme (macrophytes, macroinvertebrates, and fish);
- Site location information for the field survey sites used for each component of the baseline biological monitoring programme (macrophytes, macroinvertebrates, and fish);
- Methodology applied for analysing data obtained from the field surveying of each components of the baseline biological monitoring programme (macrophytes, macroinvertebrates, and fish);
- Results and interpretation of data obtained from the field surveying of each components of the baseline biological monitoring programme (macrophytes, macroinvertebrates, and fish);
- Recommendations for future (post-works) monitoring requirements at the site (to be detailed in subsequent report following completion of baseline biological monitoring programme).

I2 Site Information

I2.1 Cudworth Dyke Catchment

The Cudworth Dyke YW WFD river restoration pilot site falls within the extent of the 'Cudworth Dyke from Source to River Dearne' (GB104027063230) waterbody, as defined within the Humber RBMP[1].

Cudworth Dyke is a tributary of the River Dearne, located to the north-east of Barnsley, West Yorkshire. The waterbody is sourced from the predominately agricultural land to the north of the towns of Shafton and Briefly. It initially flows in a westerly direction for approximately 3km towards Royston, before flowing southward for a further 5.5km to its confluence with the Dearne south of the town of Cudworth. The Cudworth Dyke waterbody drains a catchment area of approximately 26.6km^2, including the urban areas of Royston, Carlton, Shafton and Cudworth.

Further catchment characteristics are outlined within the Cudworth Dyke Baseline Geomorphological Assessment & Optioneering Report[2].

I2.2 YW Restoration Reach (Sandybridge Dyke)

Following the completion of baseline geomorphological assessment, stakeholder engagement workshops, and river restoration optioneering (2012-2013), YW have identified the Sandybridge Dyke reach towards the upstream end of the Cudworth Dyke waterbody for the implementation of a pilot WFD river restoration scheme.

This reach encompasses the stretch of watercourse between Sandybridge Lane (SE3822511502) and the upstream end Pools Ing (SE3926007127), flowing westward immediately south of the Rabbit Ings site.

Further site information and details of the proposed restoration works are provided within the Cudworth Dyke Baseline Geomorphological Assessment & Optioneering Report[2].

[1] EA (2009) River Basin Management Plan Humber River Basin District
[2] Arup (2013), YW WFD River Restoration Pilots, Cudworth Dyke, Baseline Geomorphological Assessment & Optioneering Report

I3 Field Methodology

I3.1 Macroinvertebrates

Macroinvertebrate samples were taken at pre-defined sample sites within the catchments, positioned in suitable areas to assess actions of the proposed restoration and include both control and restoration sites. A variety of sampling techniques were used.

To ensure compatibility with standard monitoring data and EA protocols, one of these techniques was a three minute kick sample following Agency guidelines[3,4,5]. These will allow interpretation of the macroinvertebrate assemblage present across a variety of habitats, and the composition of standard indices used to examine water quality (BMWP and ASPT) and flow (LIFE) as well as determining WFD classification. Due to the aim of the project being assessing the impact of river restoration techniques, the general approach of the standard kick sample (amalgamating data from multiple habitats) was evolved to allow greater ability of interpretation. Habitat specific kick/sweep samples were collected to identify which specific fauna were present in which habitat, which when combined with the forthcoming detailed geomorphological mapping of each habitat will assist in both guiding restoration design and allowing a semi-quantitative analysis of expected changes occurring through new habitat creation. Surber sampling was used to allow a more quantitative interpretation of results, due to the likely multiple drivers impacting on assemblage composition. Further to this, due to heavy siltation and deep water, dredging was undertaken at some sites to replace the standard 3 minute kick sampling.

Methodologies for these four sampling techniques are described below:

I3.1.1 Three minute kick/sweep samples

The three minute kick/sweep sampling method uses a standard 500 µm mesh hand net. Within each three minute period, all habitat types at the sample site were sampled.

To collect the sample in running water the pond net was placed on the riverbed and the area just upstream of the net was disturbed with a foot in a kicking motion. The animals are then carried downstream by the current into the net. In standing water/marginal dead water the net was swept through the disturbed area. For habitats such as macrophyte beds and underwater tree roots the net was moved through the area in a sweeping motion.

An additional one minute hand search of other habitat structures such as large stones/woody debris was also undertaken by gently rubbing the stones in the water letting any animals be carried downstream into the net.

Any amphibians or fish caught whilst sampling were noted on the recording sheet and returned to the water.

Samples collected were then placed in a labelled 2.5 l sample tub, preserved using methanol and returned to the laboratory for analysis.

[3] Environment Agency (2012), Freshwater macro-invertebrate sampling in rivers, Operational Instruction 018_08
[4] Environment Agency (2012), Freshwater macro-invertebrate analysis if riverine samples, Operational Instruction 024_08
[5] Environment Agency (1999), EA handbook BT001

I3.1.2 One minute habitat specific kick/sweep samples

Where habitat specific macroinvertebrate data was required, one minute kick/sweep samples were collected.

As with the three minute kick/sweep sampling a standard 500 µm mesh hand net was used but only a single habitat was sampled.

To collect the sample in running water the pond net was placed on the riverbed and the area just upstream of the net was disturbed with a foot in a kicking motion. The animals are then carried downstream by the current into the net. In standing water/marginal dead water the net was swept through the disturbed area. For habitats such as macrophyte beds and underwater tree roots the net was moved through the area in a sweeping motion.

Any amphibians or fish caught whilst sampling were noted on the recording sheet and returned to the water.

Samples collected were then placed in a labelled 1.5 l sample tub, preserved using methanol and returned to the laboratory for analysis.

I3.1.3 Surber sampling

Surber samples were taken for quantitative analysis of macroinvertebrate communities in habitat specific areas (i.e. riffles or glides).

The Surber sampler consists of a 12" x 12" horizontal frame that sets on the stream bottom to border the sampling area and a hand rake is used to stir up the bottom sediments and macroinvertebrates. The standard size net measures 9" diameter and 24" long and is attached to the vertical frame to catch the macroinvertebrates and sediments as they flow into the net. Sampling is timed for one minute per surber sample and each habitat is sampled three times to provide replicates.

Any amphibians or fish caught whilst sampling were noted on the recording sheet and returned to the water.

Samples collected were then placed in a labelled 1.5 l sample tub, preserved using methanol and returned to the laboratory for analysis.

I3.1.4 Dredge sampling

Dredge samples were taken for macroinvertebrate communities in areas of deeper water and soft sediments.

A standard Environment Agency specification dredge net with a 500 µm was deployed into the sampling reach. The dredge was then pulled across the sediment for 5 m and the resulting dredged material placed in a labelled 2.5 l sample tub, preserved using methanol and returned to the laboratory for analysis.

I3.1.5 Environmental variables

In conjunction with macroinvertebrate samples, the following environmental variables are collected together with standard RIVPACS data (substrate, bank-side vegetation etc.)

- pH
- Temperature
- Conductivity
- Salinity
- Total Dissolved Solids
- Dissolved Oxygen (%)
- Dissolved Oxygen (mg/l)

I3.2 Macrophytes

Macrophyte sampling was undertaken following the EA Macrophyte Survey Methodology (LEAFPACS)[6,7]. 100 m stretches of river were sampled during macrophyte growing season to establish the presence of each taxa and to estimate percentage cover across the area surveyed. Other variables such as algal cover were also recorded. Identification was undertaken primarily in the field, though samples are taken for further analysis in laboratory conditions if required.

I3.3 Fish

All fish survey work was carried out using hand-held electric fishing. The gear used was standard single anode PDC generator-driven electric fishing equipment (Electracatch control box with 50 or 100Hz pulsed-DC output at 220 volts and variable current). All electric fishing equipment and modes of operation comply with the EA Health and Safety Regulations. All rivers were sampled by wading upstream, utilising a minimum of a three man survey team. At the end of each survey all equipment was switched off as per EA Electric fishing guidelines and relevant data collected.

At the survey sites, approximately 50m (or at least 100m^2) of river was to be fished in an upstream direction three consecutive times, where possible. The number of fish of each species in each catch was recorded and the length (fork length, nearest mm) measured. Quantitative sampling using stop nets was to be carried out to obtain absolute estimates of population density using the Carle & Strub (1978)[8] method and the efficiency of the sampling effort (probability of capture (P) derived and validated using Chi squared test. All fish captured were released where they were captured following completion of data collection.

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[6] Environment Agency (2011), Surveying freshwater macrophytes in rivers, Operational Instruction 131_07
[7] WFD UK TAG (2008), River Assessment Methods, Macrophytes and Phytobenthos, Macrophytes (River LEAFPACS)
[8] Carle F.L. & Strub M.R. (1978) A new method for estimating population size from removal data. *Biometrics* **34**, 621-830.

I4 Field Survey Locations

I4.1 Initial Catchment Scale Monitoring (Autumn 2012)

Initial baseline monitoring surveys were undertaken in Autumn 2012 at the catchment scale to provide a broad coverage of the entire Cudworth Dyke waterbody (from Sandy Bridge to the confluence with the River Dearne). At this stage, the extent and nature of the YW river restoration works along the watercourse were yet to be decided. As such, these initial baseline monitoring surveys were undertaken in parallel with the baseline geomorphological assessment and optioneering works (described previously), in order to obtain an up-to-date overview of the existing condition of the watercourse

This included baseline surveys of macrophytes, macroinvertebrates, and fish. The locations of the survey sites for each of these components are described in the below sections.

I4.2 Macrophytes

Macrophyte surveys were undertaken on four stretches of river during September 2012. The locations of these survey sites are shown in **Figure 1** and grid references are provided in **Table 1** below.

Survey sites were selected to capture key geomorphological reaches wherein restoration works may be undertaken and to represent a variety of habitat conditions evident along the length of the watercourse.

Table 1: Macrophyte survey site locations for initial catchment-scale baseline monitoring along Cudworth Dyke (Autumn 2012)

Site Name	Site Location (NGR)		
	Upstream	Middle	Downstream
Upstream Pool Ings	SE3797611510	SE38002 11437	SE3805111448
Nature Reserve	SE3788510228	SE 37918 10236	SE3788510228
D/S Catton March footbridge	SE3300709452	SE38054 09427	SE3305309391
D/S Rings Farm	SE3397107820	SE38985 07777	SE3899407739

I4.3 Macroinvertebrates

Macroinvertebrate surveys were undertaken during October 2012 from similar areas of the watercourse as the macrophyte surveys (described above). The locations of these survey sites are shown in **Figure 2a** and **Figure 2b**, and grid references are provided in **Table 2** below. The table also shows the type of sampling undertaken at each site.

Table 2: Macroinvertebrate survey site locations for initial catchment-scale baseline monitoring along Cudworth Dyke (Autumn 2012)

Site No.	Sample Type / Method	Site Location		Site Name / Description	General Area
		Easting	Northing		
25	3 min kick	437672	410947	Pool Ings 3 min kick	Pool Ings
26a; 26b; 26c	Surber	437676	411001	Pool Ings Riffle Surbers (3x1 min surber samples from 1 riffle)	Pool Ings
(40)	Surber	437684	410982	Pools Ings Glide Surbers (3x 1 min surber samples from 1 glide)	Pools Ings
28	mixed dredge/ sweep sample	437897	410255	Cudworth Nature Reserve no 1	Nature Reserve
29	mixed dredge/ sweep sample	437941	410220	Cudworth Nature Reserve no.2	Nature Reserve
30	mixed dredge/ sweep sample	437770	410259	Cudworth Nature Reserve no. 3	Nature Reserve
31	3 min kick	438030	409452	Cudworth (footbridge) (near Catton Marsh) 3 min kick	Cudworth (footbridge)
32a; 32b; 32c	Surber	438028	409449	Cudworth (footbridge) (near Catton Marsh) Riffle Surbers (3x 1 min surber samples at 1 riffle)	Cudworth (footbridge)
33a; 33b; 33c	Surber	438035	409443	Cudworth (footbridge) (near Catton Marsh) Glide Surbers (3x 1 min surber samples from 1 glide)	Cudworth (footbridge)
34	3 min Kick	438988	407762	(Police Farm) Ring Farm 3 min kick	Police Farm
35a; 35b; 35c	Surber	438987	407750	(Police Farm) Ring Farm Glide/Run Surbers (3x 1 min surber samples from 1 glide/run)	Police Farm
36a; 36b; 36c	Surber	438989	407762	(Police Farm) Ring Farm Riffle Surbers (3x 1 min surber samples from 1 riffle)	Police Farm
37	3 min kick	438104	411456	Sandy Bridge Dike (Upstream Pool Ings) 3 min kick	Sandy Bridge Dike

38a; 38b; 38c	Surber	438026	411441	Sandy Bridge Dike (Upstream Pool Ings) Riffle Surbers (3x 1 min surber samples at 1 riffle)	Sandy Bridge Dike
39a; 39b; 39c	Surber	438018	411443	Sandy Bridge Dike (Upstream of Pool Ings) Glide/Run Surbers (3x 1 min surber samples at 1 glide/run)	Sandy Bridge Dike

I4.3.1 Fish

Electro-fishing surveys were attempted at seven stretches of the watercourse in September 2012. However, due to issues relating to site accessibility and safety (due to the amount of bank-side vegetation and in-channel silt encountered respectively) surveys were only completed at four of the sites. The locations of these survey sites are shown in **Figure 3** and grid references are provided in **Table 3** below.

Table 3: Fish survey site locations for initial catchment-scale baseline monitoring along Cudworth Dyke (Autumn 2012)

Site No. / Ref	Site Location (NGR)	Survey Length (m)	Survey Type / Method
CControl	SE 388 116	50	Electric fishing (single run, as no trout captured)
C1	SE 383 115	50	Electric fishing (single run, as no trout captured)
C2	SE 376 111	50	Electric fishing (single run, as no trout captured)
C3	SE 376 108	50	Electric fishing (single run, as no trout captured)
C4	*Not surveyed*		
C5	*Not surveyed*		
C6	*Not surveyed*		

I4.4 Targeted Monitoring around Sandybridge Dyke (Spring & Autumn 2013)

Following definition of the extent of the YW river restoration works to be undertaken along the Sandybride Dyke reach (towards the upstream end of the Cudworth Dyke waterbody), a targeted programme of baseline monitoring surveys has been developed in order to provide increased coverage of this restoration reach and the adjacent reaches immediately upstream and downstream. These targeted baseline monitoring surveys are being undertaken in parallel with the outline design works for the river restoration scheme, in order to provide detailed, localised information on the existing biological and physic-chemical condition of the watercourse.

This includes baseline surveys of macrophytes and macroinvertebrates. The locations of the survey sites for each of these components are described in the below sections. Fish surveys have not been included due to the lack of key fish species recorded within the upper catchment during the initial catchment-scale fish surveys (see Section 5.1.3 above), and also due to the practicalities of undertaking electro-fishing at the site relating to accessibility, high amounts of in-channel silts causing health and safety issues, and high levels of water conductivity affecting the electro-fishing equipment.

I4.4.1 Macrophytes & Macroinvertebrates

Macrophyte and macroinvertebrate surveys are being continued as part of the 2013 targeted baseline monitoring programme around the YW river restoration reach along Sandybridge Dyke. Some of the existing survey sites from the Autumn 2012 catchment-scale monitoring programme (described in Section 5.1 above) located around the vicinity of the restoration reach have been retained and resurveyed. In addition, additional survey sites have also been included within and around the restoration site, in order to increase the coverage of the baseline monitoring being undertaken.

The location and type of each of the macrophyte and macroinvertebrate survey sites are outlined in **Table 4** and **Table 5** below, respectively. The location of the survey sites are also shown in **Figure 4.** The nature of these survey sites is also described in further detail in the following sections.

Table 4: Macrophyte survey site locations for 2013 targeted baseline monitoring around Sandybridge Dyke restoration scheme

Site Name	Site Location (NGR)			Purpose
	Upstream	Middle	Downstream	
*Existing site from Autumn 2012 catchment-scale baseline monitoring *:*				
Upstream Pool Ings	SE3797611510	SE3800211437	SE3805111448	Impact Site
*Additional sites surveyed for 2013 targeted monitoring (Autumn only)**:*				
Restoration Reach	TBC	TBC	TBC	Impact Site
Upstream Restoration Reach	TBC	TBC	TBC	Upstream Control

** Site utilised as part of targeted monitoring programme but not to be resurveyed in 2013*
*** One season per year only required for macrophyte surveys (late summer)*

Table 5: Macroinvertebrate survey site locations for 2013 targeted baseline monitoring around Sandybridge Dyke restoration scheme (Spring & Autumn)

Site No.	Sample Type / Method	Site Location		Site Name / Description	Purpose
		Easting	Northing		
Existing sites from Autumn 2012 catchment-scale baseline monitoring; sites resurveyed for Spring & Autumn 2013 targeted baseline monitoring:					
25	3 min kick	437672	410947	Pool Ings 3 min kick	Downstream Site
26a; 26b; 26c	Surber	437676	411001	Pool Ings Riffle Surbers (3x1 min surber samples from 1 riffle)	Downstream Site
40 (a, b, c)	Surber	437684	410982	Pools Ings Glide Surbers (3x 1 min surber samples from 1 glide)	Downstream Site
37	3 min kick	438104	411456	Sandy Bridge Dike (Upstream of Pool Ings) 3 min kick	Impact Site
38a; 38b; 38c	Surber	438026	411441	Sandy Bridge Dike (Upstream Pool Ings) Riffle Surbers (3x 1 min surber samples from 1 riffle)	Impact Site
39a; 39b; 39c	Surber	438018	411443	Sandy Bridge Dike (Upstream of Pool Ings) Glide/Run Surbers (3x 1 min surber samples from 1 glide/run)	Impact Site
Additional sites surveyed for Spring & Autumn 2013 targeted baseline monitoring::					
41	3 min kick	437734	411321	Restoration Reach downstream end 3 min kick	Impact Site
42	3 min kick	438295	411537	Restoration Reach upstream end 3 min kick	Impact Site
43a; 43b; 43c	Surber	438292	411535	Restoration Reach upstream end Riffle Surbers (3x 1 min surber samples from 1 riffle)	Impact Site
44	Surber	438280	411527	Restoration Reach upstream end Glide Surbers (3x 1 min surber samples from 1 Impact Site (Sandybridge Dike)glide)	Impact Site
45	3 min kick	438936	411726	Upstream of Restoration Reach 3 min kick	Upstream Control Site

46	Surber	438932	411724	Upstream of Restoration Reach Riffle Surbers (3x 1 min surber samples from 1 riffle)	Upstream Control Site
47	Surber	438951	411730	Upstream of Restoration Reach Glide Surbers (3x 1 min surber samples from 1 glide)	Upstream Control Site

I4.4.1.1 Upstream Control Sites

The upstream limit of the YW river restoration reach has been fixed at the downstream end of the railway embankment crossing culvert at Sandybridge Lane. No macrophyte and macroinvertebrate survey sites were located within the extent of the restoration reach as part of the Autumn 2012 catchment-scale baseline monitoring works (see Sections 5.1.1 and 5.1.2). Consequently, a new macrophyte upstream control survey site and three macroinvertebrate upstream control survey sites have been located along the reach immediately upstream of this crossing.

As part of the 2013 targeted baseline biological monitoring programme, macrophyte surveys will be undertaken once (Autumn) and macroinvertebrate samples will be collected twice (Spring and Autumn) at these sites.

This area is not expected to be impacted by the restoration works.

I4.4.1.2 Impact Sites (Restoration Reach)

One macrophyte survey site was located within the extent of the restoration reach as part of the Autumn 2012 catchment-scale baseline monitoring works (see Sections 5.1.1). Following the definition of the restoration reach extent, this site has been retained and an additional macrophyte survey site has also been located within the extent of the restoration reach to provide increased coverage.

As part of the 2013 targeted baseline biological monitoring programme, macrophyte surveys will be undertaken once (Autumn) at the new survey site (but will not be resurveyed at the existing site, as repeat surveys are typically only required on a 3 year basis).

Three macroinvertebrate survey sites were located within the extent of the restoration reach as part of the Autumn 2012 catchment-scale baseline monitoring works (see Section 5.1.2; sample site no. 37, 38, 39). Following the definition of the restoration reach extent, these sites have been retained and four additional macroinvertebrate survey sites (reflecting changes in surrounding land use and stream morphology along the reach; sample site no. 41, 42, 43, 44) have also been located within the reach extent (between Sandybridge Lane and Pools Ings).

As part of the 2013 targeted baseline biological monitoring programme, macroinvertebrate samples will be collected twice (Spring and Autumn) at both these existing and new sites within the restoration reach.

This area is expected to be directly impacted by the restoration works.

I4.4.1.3 Downstream Sites

Retained Sites (Pools Ings):

Three macroinvertebrate survey sites were located within the reach immediately downstream of the restoration reach (at Pool Ings) as part of the Autumn 2012 catchment-scale baseline monitoring works (see Section 5.1.2, sample sites 25, 26, 40). Following the definition of the restoration reach extent, these sites have been retained, in order to assess any impacts on downstream invertebrate communities resulting from the restoration works (due to factors such as altered sediment dynamics, physic-chemical water quality parameters, improved upstream habitat quality, etc).

As part of the 2013 targeted baseline biological monitoring programme, macroinvertebrate samples will be collected twice (Spring and Autumn) at these existing sites.

Removed Sites:

A number of macrophyte and macroinvertebrate survey sites were located on reaches within the mid and lower catchment (at the Carlton Marsh Nature Reserve, downstream of the Carlton Marsh Nature Reserve, and the adjacent to the Police Farm) as part of the Autumn 2012 catchment-scale baseline monitoring works (see Section 5.1.2, sample site no. 28-36). These sites have been discontinued due to the refocusing of the project toward the upper catchment and the YW river restoration scheme along the Sandybridge Dyke reach.

I5 Data Analysis & Interpretation Methodology

I5.1 Macrophytes

The raw data outputs from the macrophyte field surveys include species list of macrophytes recorded at each site, together with information on percentage cover and percentage taxon cover.

This data is then used to gain a qualitative understanding of present environmental conditions based on standard indices and procedures. Data is interpreted statistically with respect to differing drivers and potential controls, through comparison of indices with differing divers (e.g. flow against water quality). Confounding variables are identified where possible based on comparison of Control and Impact sites.

Macrophyte surveys result in the production of five main variables. The River Macrophyte Nutrient Index (RMNI; high scores are associated with plants preferring enriched conditions), the River Macrophyte Hydraulic Index (RMHI; high scores are associated with plants of low energy flow), the number of macrophyte taxa, the number of functional groups of macrophyte taxa (how many different growth forms) and the percentage cover of algae (demonstrating enriched conditions).

For each of the indices, a ratio is calculated comparing the observed value to an expected ‘natural’ value based on the chemistry, location and physical characteristics of the watercourse. This ratio allows classification of the watercourse into WFD Ecological Potential (EP) status classes depending on the difference between the observed species and the expected fauna under natural conditions.

I5.2 Macroinvertebrates

Macroinvertebrate samples collected from the field surveys is sorted, identified and counted to mixed taxon according to the levels required by the UKTAG protocol and any rare species identified. All stages of analysis is conducted by suitably trained and experienced macroinvertebrate taxonomists and every tenth sample will be audited.

This data is then used to gain a qualitative understanding of present environmental conditions based on standard indices and procedures. Data is interpreted statistically with respect to differing drivers and potential controls, through comparison of indices with differing divers (e.g. flow against water quality) and multivariate statistics (DCA and CCA if data proves non-linear, etc). Confounding variables are identified where possible based on comparison of Control and Impact sites.

Key indices calculated include the Biological Monitoring Working Party (BMWP; indices reflecting water quality tolerance, wherein higher scores reflect dominance of species that prefer ‘cleaner’ water quality conditions), ASPT (Average score Per Taxa; BMWP/number of scoring aquatic species), and LIFE (Lotic Invertebrate Index for Flow Evaluation; indices reflecting flow tolerance, wherein higher scores reflect dominance of species that tolerate or seek higher flows).

Whilst the BMWP score gives a general indication of water quality, the number of taxa, an indication of species richness (which generally increases with ecological condition) and average score per taxon, the average water quality pressure sensitivity of the site, this only demonstrates absolute water quality at a point in time.

To convert these indices to WFD EP status classes, they are compared to what would be the expected value should the watercourse be in a 'natural' state, based on physical catchment characteristics. The ratio of the comparison in turn demonstrates how far they are from achieving Good (i.e. a natural) EP status. For example, it is possible therefore that a site with a higher 'number of taxa' score may result in a lower WFD EP class outcome than a lower scoring site; as it is dependent on how far those scores are from the watercourses' 'natural' levels of diversity in relation to their physical catchment characteristics.

This classification is undertaken using the RIVPACS methodology using the RICT model (UKTAG River Assessment methods benthic invertebrate fauna, river invertebrate classification tool, 2008).

I5.3 Fish

The data collected from the 2012 population monitoring surveys is, where possible, used to generate information on species composition, population density and age structure using classical fisheries and statistical techniques, as defined in Cowx and Fraser (2003)[9] as well as the factors affecting distribution and abundance. Scales (estimated to be more than 2000) are examined and used to determine the back-calculated growth history of trout. The age and growth, and population density data is also be used to assess recruitment and mortality schedules where possible. In addition, the HABSCORE data is used to evaluate the suitability of the site in terms of juvenile trout production.

This data is then used to derive WFD EP status classes by comparing the calculated population densities of target species (e.g. brown trout) to what would be the expected value should the watercourse be in a 'natural' state, based on physical catchment characteristics. The ratio of the comparison in turn demonstrates how far they are from achieving Good (i.e. a natural) EP status.

[9] Cowx I.G. & Fraser D.F. (2003) *Monitoring the Atlantic Salmon.* Conserving Natura 2000 Rivers Monitoring Series No. 7, English Nature, Peterborough. http://www.english-nature.org.uk/lifeinukrivers/publications/salmon_monitoring.pdf

Figures

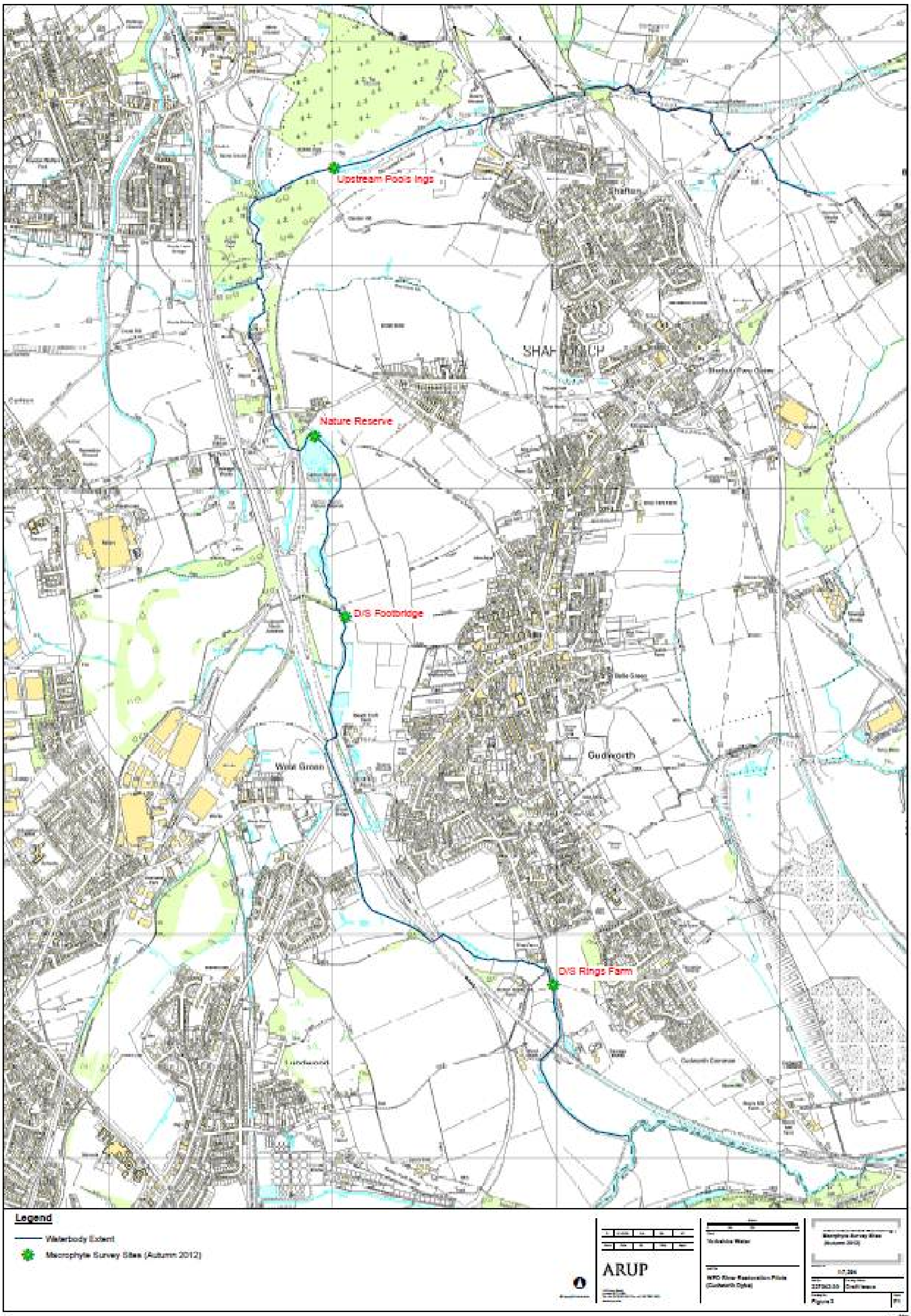

Figure 1 Macrophyte Survey Sites (Autumn 2012)

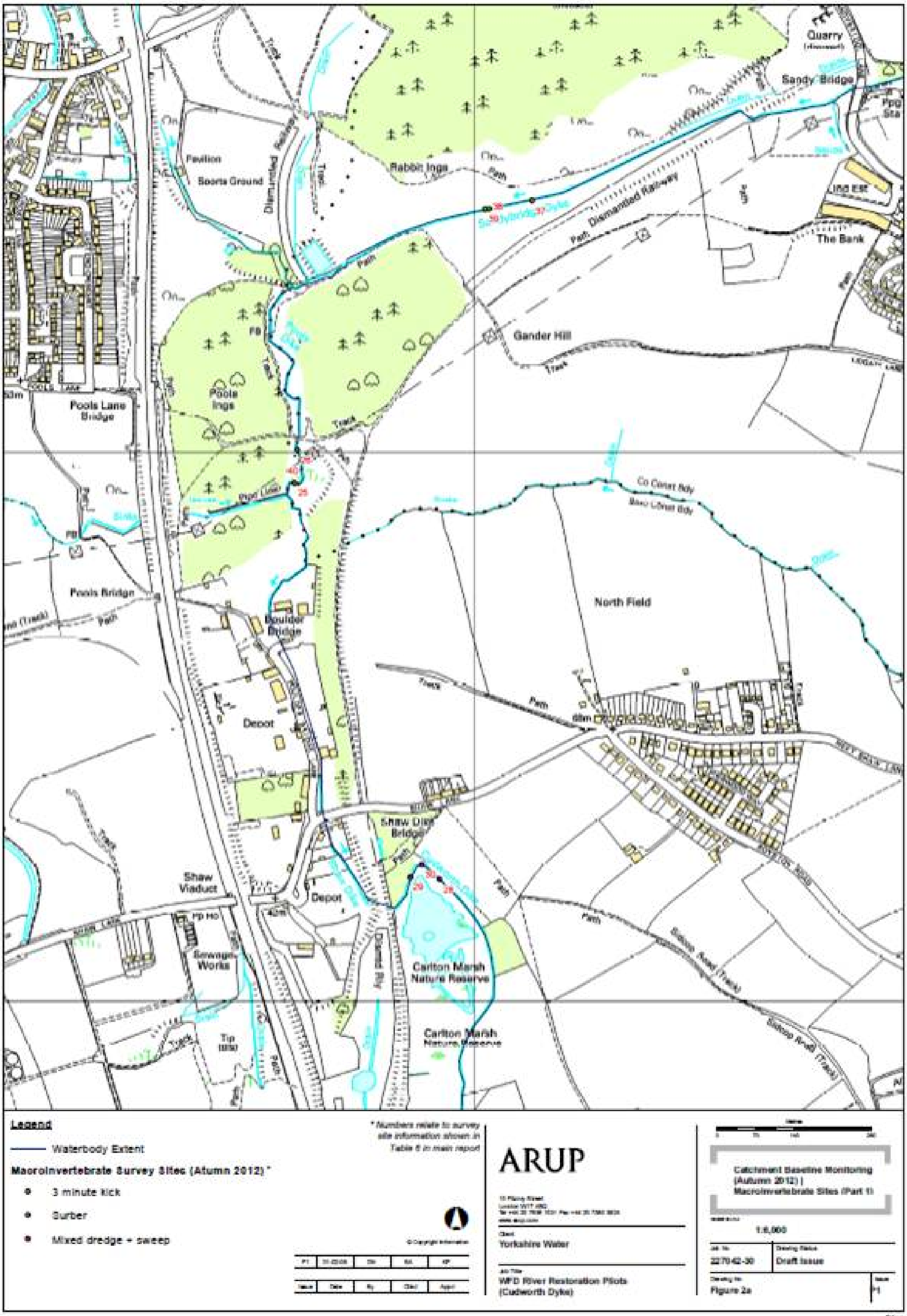

Figure 2a Macroinvertebrate Survey Sites 1 (Autumn 2012)

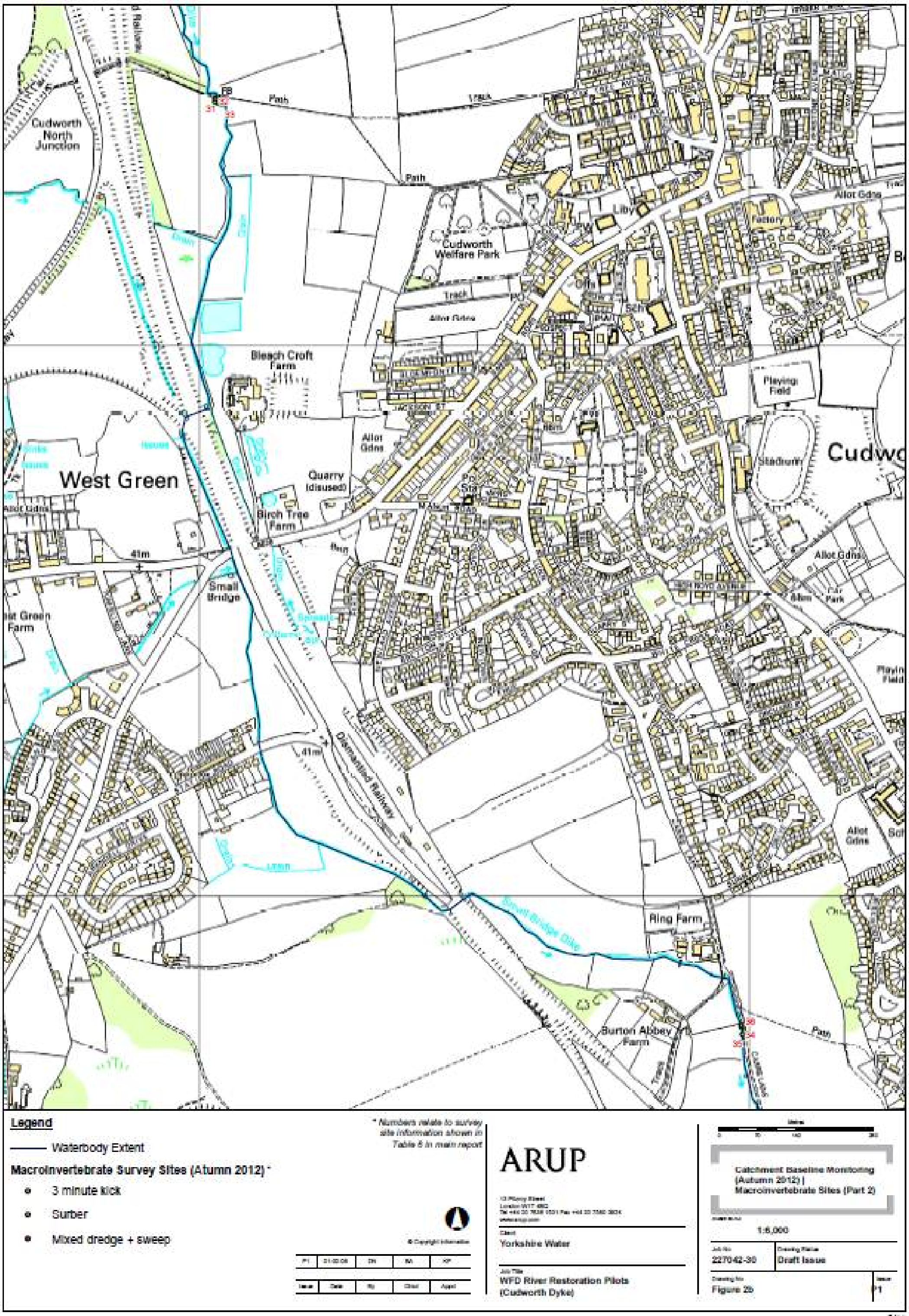

Figure 2b Macroinvertebrate Survey Sites 2 (Autumn 2012)

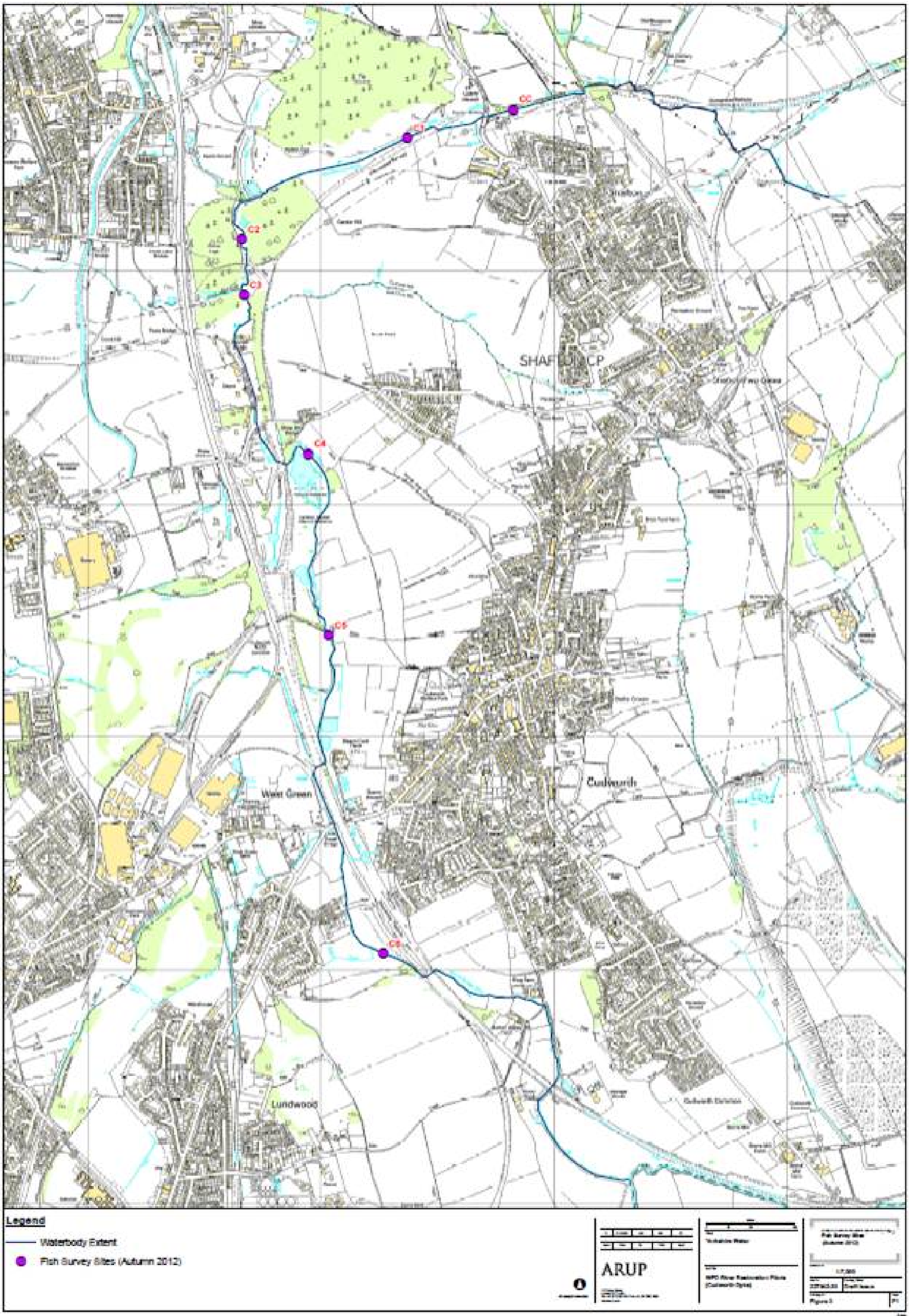

Figure 3 Fish Survey Sites (Autumn 2012)

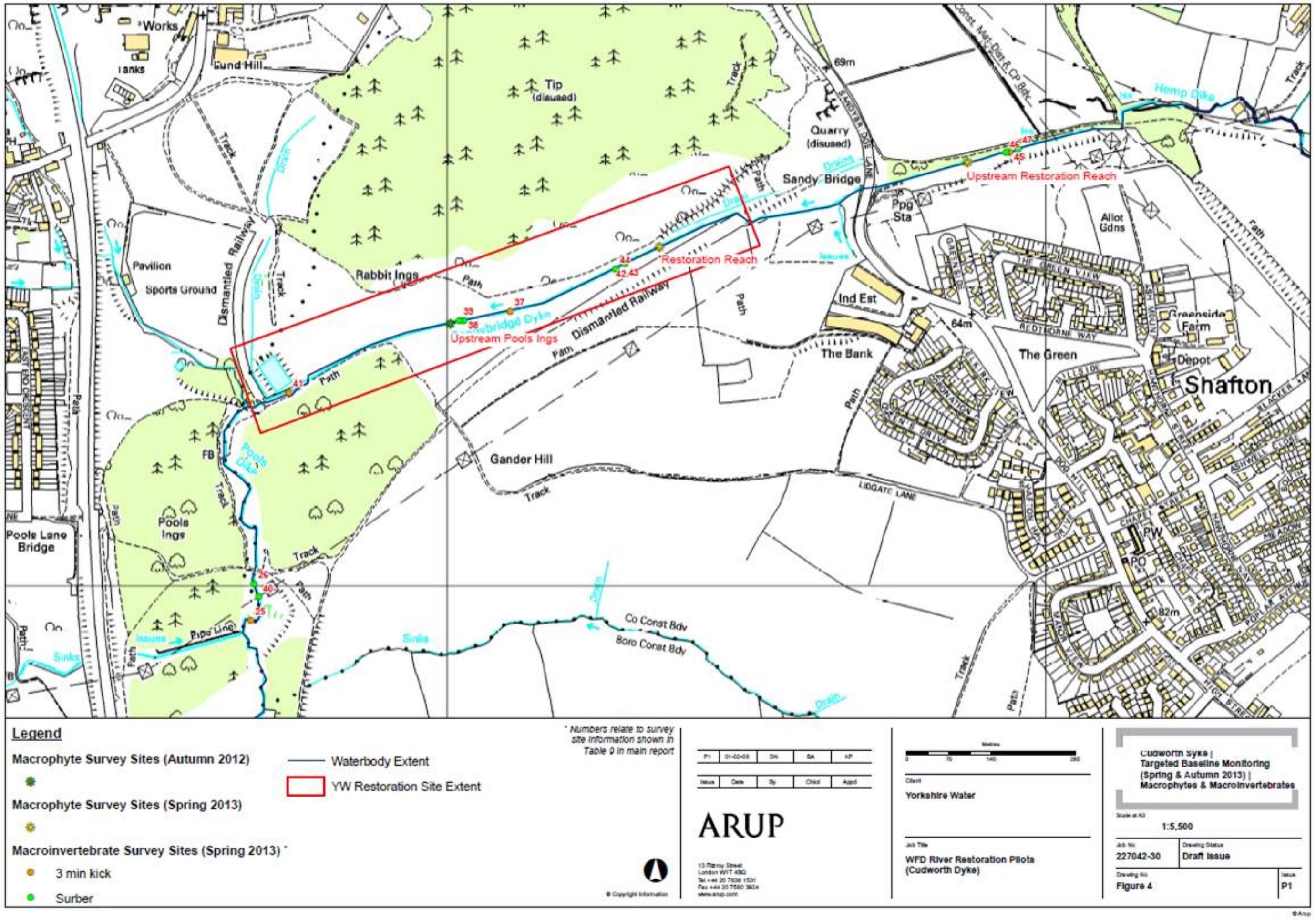

Figure 4 Targeted Macroinvertebrate and Macrophyte Survey Sites

Appendix J

Proposed HS2 Route

J1 Route

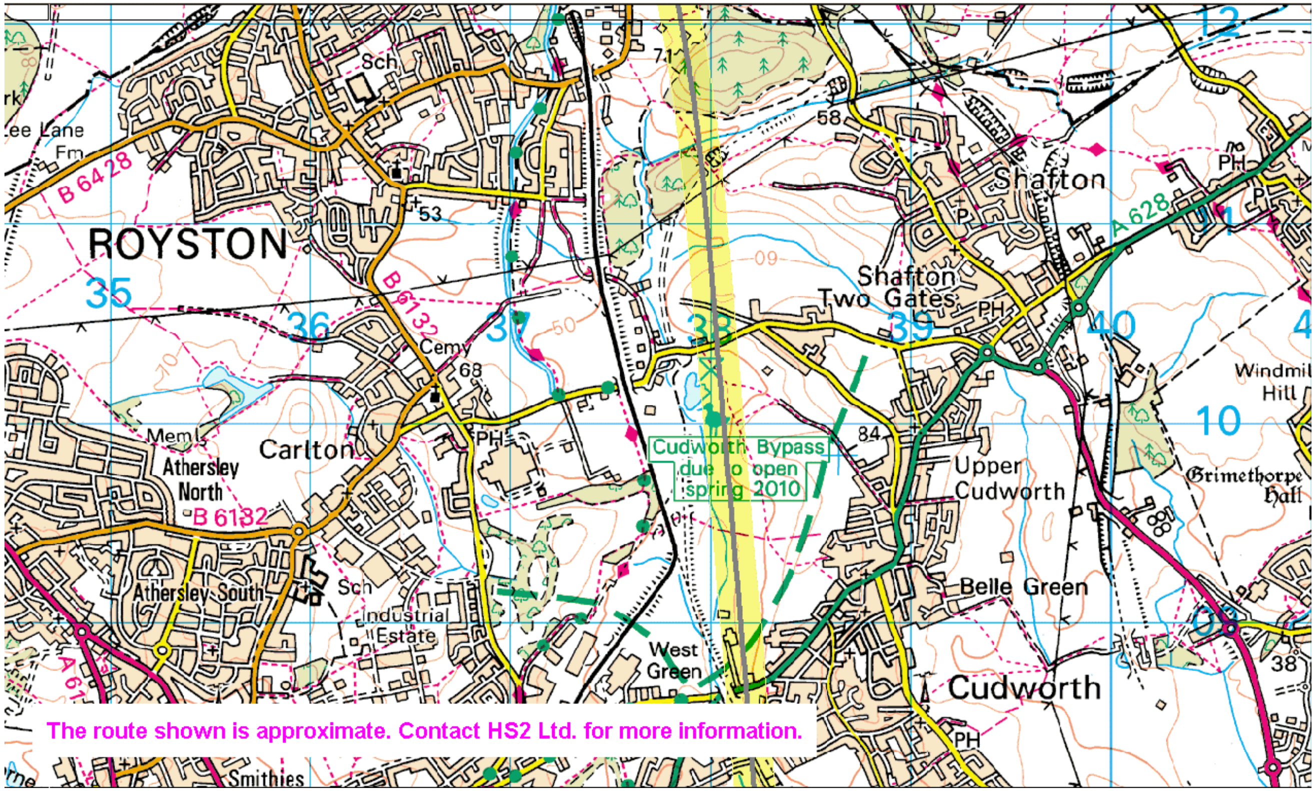

Figure 1 Proposed route of HS2 through Cudworth Dyke