Wansbeck Nature Recovery Plan

River Restoration

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Quality information

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1. Introduction

Study Aims

1.1 AECOM was instructed by the Environment Agency (EA) in January 2022 to prepare a Nature Recovery Plan for the River Wansbeck Catchment. The purpose of the Nature Recovery Plan is to inform future project work and investment in the Wansbeck Catchment and to integrate freshwater habitat and terrestrial habitat restoration and creation projects.

1.2 The project has been split into two distinct components:

1) a Wansbeck River Restoration Plan; and

2) a Wansbeck Habitat Restoration and Creation Plan.

1.3 This report is the River Restoration Plan, the aims of which are two-fold: the first is to identify a long list of potential river restoration options at the catchment scale; and the second is to present a shortlist of those options in more detail. This will take into account ongoing river restoration and enhancement schemes that have taken place, or have been identified as an opportunity, within the Wansbeck catchment. Accordingly, the river restoration plan will link with the nature network modelling to identify areas that would provide a rich, well-connected and high-functioning mosaic of both terrestrial and riverine habitats.

1.4 This report should be read with reference to the Wansbeck Habitat Restoration and Creation Plan prepared by AECOM (2022).

Study Site

1.5 The River Wansbeck (Figure 1-1) drains a 330 km^2 catchment in Northumberland, north-east England, discharging to the North Sea at Ashington. The catchment comprises around 750 km of mapped watercourses that fall within 11 Water Framework Directive (WFD) waterbodies (sub-catchments). Tributaries include the Bothal Burn, Delf Burn, Ray Burn, Hart Burn and River Font. The character of the catchment has been defined both by natural and anthropogenic influences; the retreat of glaciers around 17,000 years ago gave rise to a distinctive landscape, with a thick veneer of till material covering most of the catchment, within which the surface water network has eroded deeply incised valleys. Extensive de-forestation and, more recently, intensive arable and pastoral farming, upland land management (such as coniferous plantations), coal mining, and water resource management have, in combination, significantly impacted the watercourses within the Wansbeck catchment.

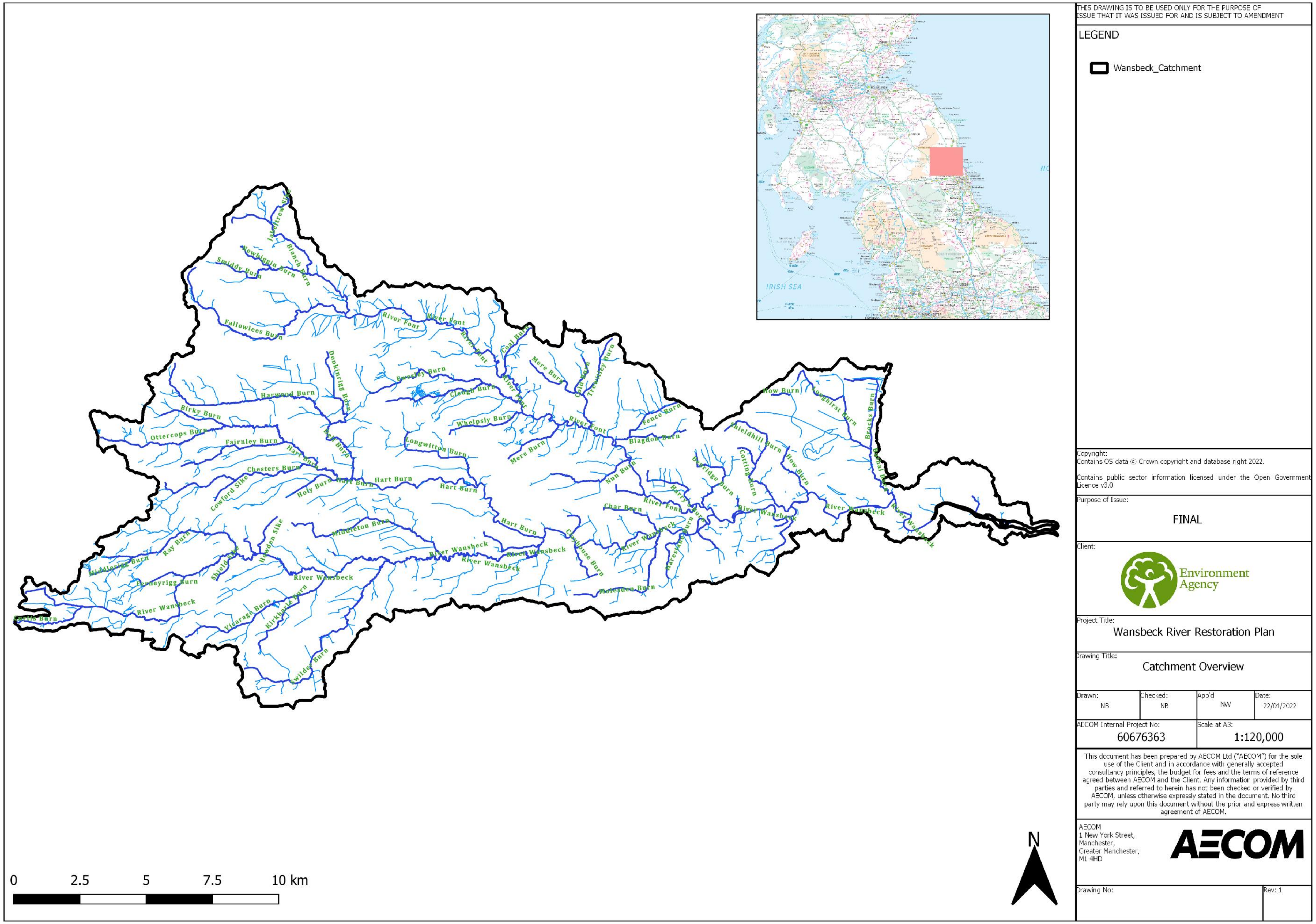


Figure 1-1 Overview of the Wansbeck Catchment

2. Methodology

Overview

2.1 The project methodology has comprised the following tasks:

- A desktop review of existing reports to inform baseline conditions;
- A data gathering exercise to collate GIS information relevant to the study area;
- Development of a longlist of river restoration options;
- Consultation with stakeholder groups;
- Selection of a shortlist of river restoration sites and detailed analysis

2.2 Further information about the different steps is provided in the following sub-sections.

Catchment Evaluation

Establishing Baseline

2.3 A desk-based study was carried out to capture information pertaining to Wansbeck catchment that is not attainable through site survey but would support the understanding of baseline conditions at the catchment scale. Review of relevant information relating to the study area was undertaken to develop a broad understanding of the catchment, its watercourses, and surrounding areas. The following data sources were used for the desk study:

- Contemporary Ordnance Survey (OS) maps
- Geology and soil data
- Aerial photography
- EA data (aerial LiDAR and WFD data)
- Historical maps
- Designated areas
- Hydrological information

Reach Delineation

2.4 The Wansbeck Catchment is comprised of over 750km of mapped watercourses; therefore, it was deemed impractical to review river restoration opportunities on a 500m reach-by-reach basis, which would generate hundreds of potential sites. Instead, the catchment was divided by WFD water body, of which there are 11, and river restoration opportunities were identified on named rivers within each WFD water body.

Identification of River Restoration Opportunities

Longlist

2.5 A comprehensive desk-based study was undertaken to identify potential pressures that may contribute to the overall degradation of watercourses within the Wansbeck catchment. A wide range of open-source and licenced spatial data, coupled with novel spatial analysis methodologies, were utilised in this assessment to determine where these pressures exist, and any opportunities that may be present to remediate them. In addition, the desk study revealed constraints to river restoration, such as existing woodland reaches which likely do not require restoring; urban areas where restoration may be difficult or prohibitively high-risk, constrained, or expensive; and incised, laterally confined reaches where steep topography may limit opportunities for or impede delivery of restoration. A brief summary of data sources and methodologies is provided in Table 2-1.

Table 2-1. Summary of key outputs and the spatial data used to generate them.

Output/variable	Data Sources	Data Description	Application in Optioneering
Elevation	EA Open LiDAR Data	2m Aerial National LiDAR Programme Digital Terrain Model (DTM) data.	These data provided the basis for additional morphological analysis, such as delineation of valley bottoms and the topographic character of the catchment.
Valley bottoms	EA Open LiDAR Data processed to remove sinks and created a hydraulically smooth surface	Unconstrained extent of floodplain generated from 2m DTM data using the Multiresolution index of valley bottom flatness tool provided by SAGA GIS and hosted on QGIS 3.16.	The outputs indicate where extensive lateral river restoration measures, such as floodplain-reconnection and 'stage 0' techniques, could be successfully implemented.
Channel sinuosity	Ordnance Survey Water Network	The most detailed available spatial dataset of the mapped surface water network.	Sinuosity was derived by calculating both the straight-line distance and absolute distance between nodes and dividing the results. Sinuosity is a simple proxy for likely channel habitat diversity, and likely historic realignment (straightening).
Valley side slope	EA Open LiDAR Data processed to remove sinks and created a hydraulically smooth surface	Areas of the catchment that are >10% gradient. This is the inverse of the valley bottoms layer and effectively shows where river channels are laterally confined by steep slopes.	This provides areas of topographic constraint where wide-scale restoration would not be attainable or appropriate.
Areas of constraint and opportunity	CEH Land use	Remotely sensed raster-based land-use data derived from the Copernicus Sentinel-2 satellite platform. Improved grassland, arable, and coniferous forestry landcover types are considered available for restoration while all remaining classes are considered as a constraint.	These two sets of variables were merged to create a simplified map of areas of constraint and opportunity.
Bedrock, superficial and linear geology	BSG Geology	Vector-based 1:50,000 scale bedrock, superficial and linear geology data supplied by the British Geological Survey under the EA's conditional licence.	Superficial geology indicates areas where river systems once occupied extensive depositional valleys, as signified by extensive alluvial deposits and river terrace sequences. These areas tie-in with the valley bottoms layer described above.
Soils	National Soil Map of England and Wales - NATMAP	Vector-based simplified rendition of the national soil map classified into 30 distinct soil types.	The soil layer provides an indication of hydrological and wetland units, associated with where river systems once occupied extensive valleys but have since been confined to straightened, single-thread channels.
Aerial imagery	Google Earth	High resolution satellite and aerial imagery from multiple years.	Visual assessment of the Wansbeck system provided an insight into the physical character of the drainage network, floodplain conditions and potential constraints which may limit opportunities for restoration.
WFD Classifications	Environment Agency Catchment Data Explorer	Online resource for WFD classification data, reasons for not achieving good, objectives and spatial data.	Delineation of sub-catchments, denoted by WFD water body and targeting of measures to meet specific objectives, such as improving water quality through targeting of agricultural practices.

2.6 The suite of spatial data and analyses methodologies described above were used in combination to reveal areas of river restoration opportunity. However, a degree of expert judgment was employed to further scrutinise these areas, identify specific opportunities and assign a level of intervention: either low, medium or high. For example, a reach that sits within a flat depositional valley with clear signs of realignment and palaeo features within its floodplain, successions of river terraces at the valley periphery and an alluvial valley floor, would be an obvious candidate for high intervention, valley-scale restoration. Conversely, a reach that is sinuous, but heavily poached with no discernible riparian zone would be a candidate for lower intervention measures such as implementation of stock fencing and riparian habitat.

2.7 In order to rationalise the longlist of river restoration opportunities identified through desk-study, a multi-criteria analysis (MCA) was performed to score each site based on a number of key parameters.

Shortlist

2.8 The longlist of restoration options was refined down to a shortlist of the six top-scoring sites based on the MCA described above. Sites that are the focus of existing projects by other parties, in particular Northumberland Rivers Trust, The National Trust and Groundwork North East, were discounted from the shortlist and the next best scoring site was taken forward. Each of the six sites were then studied in more detail during targeted walkover surveys.

Walkover Surveys

2.9 A series of geomorphological walkover surveys were conducted by a Chartered Geomorphologist on 23rd, 24th, and 25th March 2022 to establish baseline geomorphological characteristics of the river reaches and their floodplains identified in the shortlist of opportunities within the Wansbeck Catchment. In addition, the practical feasibility of the range of opportunities identified during the desk study were confirmed on site, and any additional opportunities were noted.

2.10 Mobile mappers running a custom ESRI ArcCollector field survey app were employed to expedite field surveys, data entry tasks and mapping along with collecting geo referenced photographs. The bespoke survey followed the principles of fluvial audit and captured data on the watercourse including, but not limited to:

- Reach gradient
- Planform characteristics
- Cross-sectional profile
- River bed and bank material
- Erosion and deposition
- Sediment sources and sinks
- Vegetation cover
- Channel modifications

3. Desktop Review of Existing Reports

Review of existing data sets and previous studies

Wilds of Wanney WEIF Programme: Delf Burn Sub-Catchment

3.1 The Wansbeck Partnership has a vision for the Wansbeck catchment to 'Create a sustainable River Wansbeck catchment which is an attractive, vibrant and interesting place for people to live, work, visit and invest' (Groundwork, 2021). The aim of this is to enable the catchment to become more renowned and valued, generating economic benefits for the population, fluvial environments, and wildlife. They hope to do this by improving water quality; natural processes; the condition, access of natural, cultural, and built heritage connected with the river; and resilience for businesses that utilise these.

3.2 This project focused on the Delf Burn which is a sub-catchment within the Wansbeck catchment, the overall WFD water body classification of this area has declined from moderate in 2016 to poor in 2019. The factors that have contributed to this were the combined decline of macrophytes and phytobenthos from high WFD status in 2013, good WFD status in 2014 & 2016 to moderate WFD status in 2019. In addition to the decline of fish from moderate WFD status in 2016 to poor WFD status in 2019.

3.3 A 2021 river survey of the Delf Burn found that trout were present in the lower sections of Harwood Burn and Delf Burn, but in smaller populations than would be expected for the size and type of water body. Minnow was present throughout the sub-catchment but only in the smaller waterbodies. Some dead crayfish were observed within the catchment, however, this is not uncommon within rivers with enhanced sediment and nutrient levels, and low water quality conditions.

3.4 The study found that livestock has degraded long zones of riparian vegetation through excreta, poaching, and erosion which have caused enhanced nutrient and fine sediment input to the waterbodies. The scale of input is large enough to lead to enhanced algal growth and is enough to cause a damaging influence upon fish and invertebrate populations. Increased erosion has also been caused by the removal of gorse scrub which is greatly intensifying the input of fine sediment along sections of the sub-catchment.

3.5 The study also suggested that buffer fencing or zones of livestock exclusion would be advantageous in the catchment and enable the renewal of vegetation and increase biodiversity. This renewal would slow the flow of overland runoff, decrease peak flows, enhance infiltration, trap sediment and decrease nutrient loss from fields. If complete livestock exclusion is not possible then the exclusion of cattle would still be beneficial. Where livestock has access to the rivers separate drinking infrastructure should be installed. Much of the historical forestry within the catchment is characterised by coniferous planting that has taken place too close to the waterbodies. Any riparian buffer zones would benefit from the addition of deciduous species which would, in turn, reduce the impact of future harvesting. Planned felling of trees on overshaded sections within the catchment would help in the creation of deciduous buffer zones.

3.6 Palaeochannel restoration of straightened channels within the catchment would increase the length of the river, and majorly benefit geomorphological and habitat quality. Leaky dams on straightened sections of the watercourse would improve water quality, store sediment, and provide flood alleviation by slowing peak flows.

3.7 Overall, the study highlighted that the main issue within the sub-catchment was due to livestock access which is having a negative impact on water quality. Although tackling this problem may not solve all the issues in this sub-catchment, without addressing it WFD improvement is doubtful.

Wansbeck Barrage

3.8 Between 1974-75 a barrage was erected on the River Wansbeck close to the mouth of the Estuary near the A189 road bridge to remove 'unsightly' salt marsh and provide amenity value. The Wansbeck estuary reaches 4 km inland to the former tidal limit at Sheepwash weir, with an intertidal of c. 6000,000m^2 (Elmes et al., 1997). The barrage resulted in an 80% reduction in tidal range and has caused a loss of c. 500,000 m^2 of intertidal habitat, whilst the area downstream of the barrage demonstrates a natural tidal range, with both subtidal and intertidal habitats present (Elmes *et al*., 1997).

3.9 In addition, the barrage has had some detrimental impacts on the chemical nature of the estuary. Before the barrage was built the estuary was characterised by being well mixed especially during summertime low flow, with stratified profiles in wintertime (Lamping, 2003). In addition, dissolved oxygen levels remained constant at 70-80% (Worrall and Mcintyre, 1998). However, after the construction of the barrage, the lake demonstrates hypoxia and anoxia due to enhanced periods of saline stratification (Worrall and Mcintyre, 1998).

3.10 The barrage has caused an increase in sediment deposition, with an average sedimentation rate of 400 mm/year (Worrall and Mcintyre, 1998). This has caused the lake to progressively shallow and has reduced the overall value of the amenity lake. However, to control unwanted sedimentation and preserve ecological value it is suggested that a flushing strategy should take place whereby the lock gates of the barrage are opened for sustained periods. This should not majorly impact the body of water downstream of the barrage and it is unlikely that this will cause sediment accumulation issues in the estuary mouth and coastal area (Skinner and Coulthard, 2021).

3.11 The barrage has a height of 2.14 m Above Ordnance Datum (AOD) which enables boats to access the impounded water but allows overtopping in an attempt to maintain water quality in summer months by producing limited storage of water within the lake (Curtis and Dawson, 1978). The barrage only permits tides greater than 4.74 m Above Chart Datum (ACD[1]) to enter the lake (Lamping, 2003).

White Clawed Crayfish

3.12 In Northumberland, the white-clawed crayfish (*Austropotamobius pallip*es) populations are in decline. The River Wansbeck is the only river that contains a substantial population, with the River Aln – a catchment located north of the Wansbeck cacthement – and two of its small tributaries supporting a small population of them. The species is critically endangered in the UK and are thus listed as rare and most threatened species under Section 41 of the Natural Environment and Rural Communities Act (2006).

3.13 According to the EA and Northumberland County Council, any watercourse draining to the river may accommodate white-clawed crayfish. The exact details as to why the white-clawed crayfish populations are in decline in Northumberland are not fully understood but may in part be due to diffuse pesticide pollution and habitat degradation (Northumberland BAP, 2000). Key habitat features are a calcareous influence, channel form, presence of tree and scrub roots in channel banks, and in-channel stones and debris (Smith et al., 1996).

3.14 Based upon findings of the 2007 and 2012 surveys, no white-clawed crayfish were present in the Cotting Burn / Ful Beck system, however, they were found at the River Wansbeck confluence. The presence of a culvert on the Cotting Burn is accessible for white-clawed crayfish, however, it could reduce their upstream movement along Cotting Burn from the River Wansbeck. Although this combined with four weirs and two culverts upstream at The Dell most probably prohibit the crayfish from full access to Cotting Burn.

3.15 No white-clawed crayfish were found within the How Burn tributary, although the area does have a suitable habitat for white-clawed crayfish. Particularly the middle section that is characterised by a channel that has defined pools and riffles that contains a wide range of refuges. However, a white-clawed crayfish was located at the How Burn – River Wansbeck confluence. The reason that no crayfish were found upstream within How Burn itself is probably due to a culvert that prohibits access from the River Wansbeck.

3.16 Although the River Wansbeck is of regional importance as the only river in Northumberland that contains a substantial population of white-clawed crayfish, clearly the presence of weirs and culverts have obstructed crayfish from migrating into suitable habitats in the tributaries of the River Wansbeck; however, as noted by the National Trust (2022), barriers also prevent the non-native American signal crayfish from accessing undisturbed portions of the catchment.

Wallington

3.17 The Wallington Estate has seen a decline in biodiversity and only 9% of the Estate is categorised as priority habitat (National Trust, 2017). Currently, the estate is characterised by grassland, river corridors, wet heath, and blanket bog. The grassland and river corridors have seen a decline in biodiversity in the last 20 years. Whilst the wet heath and blanket bog habitats account for c. 70% of the priority habitats on the estate. However, Wallington Estate is aiming to restore its biodiversity by 2068 and re-establish 50% of the Estate's

[1] It has not been possible to translate this to mAOD.

land to priority habitat. They aim to do this by developing an integrated farm management system that will enable farming, wildlife, and people to prosper. They will maintain, expand, and connect key habitats, increase carbon storage through peatland restoration, and improve water quality.

3.18 Most of the habitats on the estate have been heavily modified or been intensely managed which has led to biodiversity loss, habitat fragmentation, and isolation, and species decline. There has been year-round heavy grazing which has led to reduced biodiversity across much of the Estate with the moorlands being especially impacted. In addition to this, the Estate's dependence on fertilisers and lack of species-rich boundaries is impacting the overall biodiversity of the land.

3.19 There are c. 54km of waterways flowing through Wallington and they incorporate the majority of the River Wansbeck's upper catchment. Water quality across the entire Estate has been negatively impacted by pollution caused by heavy reliance on fertilisers and livestock pressures. To enhance river corridors and water quality the Wallington Estate aims to be a key part of the National Trust's National Programme 'Riverlands', which is a catchment-based partnership working to conserve and enhance rivers with the EA. This along with the integrated farm management system will aim to stop the deterioration in water quality and biodiversity. Rivers will be allowed to flow naturally through floodplains enabling flood mitigation. Scheduled grazing patterns, the introduction of livestock watering systems, designated river crossing points, and the creation of boundaries will enable habitat to develop.

3.20 Working in collaboration with the Estate's farmers and the Forestry Commission they are aiming to enhance the area of woodland. Much of the woodland sites in the Estate are conifer dominant and have traditionally been used for shelter. The Estate is aiming to create 400 ha of broad-leaved woodland, restore 175 Ha of woodland to native woodland, and plant 1 million trees whilst maintaining key species and farmland shelterbelts.

3.21 Wet heath and blanket bogs on Wallington account for most of the priority habitats on the Estate and therefore the aim for this 250 ha area is to continue improvement. Linking up and expanding the areas of moorland will enable the reintroduction of vital species, but also enhance carbon storage and flood mitigation. However, the moorlands need more scrutiny to further manage floods and to determine the scale and type of grazing to enable the best development of the area.

4. Wansbeck Catchment Baseline

Catchment Characteristics Overview

4.1 Wansbeck upstream of the gauging station at Mitford is a ca. 300km^2 catchment of generally rural character. Topography ranges from 442 mAOD in the westernmost catchment, to a short estuary at Ashington downstream of Morpeth, the largest urban settlement. The Wansbeck headwaters descend evenly from the mountainous heaths and bogs of an extensive till plain in the west, and Harwood Forest in the north west, through a mid-catchment with steeply incised forested valleys but otherwise dominated by undulating grassland and increasing incidence of arable land towards the coast. Geology corresponds broadly with Tyne and Alston limestone bedrock in the headwaters, mid-catchment Stainmore formation mudstones and sandstones, and lower catchment Pennine coal measures.

4.2 Virtually the entire catchment is overlain with superficial tills, with terraced glaciofluvial sand and gravel deposits in gorges and deep valleys, and relatively little alluvium (which tends to be clayey given the glacial landscape evolution) until the Morpeth floodplain and tidal flats. Hydrology through the catchment is generally flashy but impounded for 30km^2 in the upper catchment at Font reservoir with depleted flows through the lower Font river tributary to Wansbeck. There is also a flood storage dam at Mitford that impounds ~60% of the upstream catchment with outflow to the lower reaches constrained to 150m^3/s. Coal measures in the lower catchment form aquifers, but these are multi-layered and yield discontinuous supplies to fluvial valleys, due to extensive faulting and fissures that encase sandstones with slow-seepage mudstones and shales, with some areas effectively capped by boulder clay.

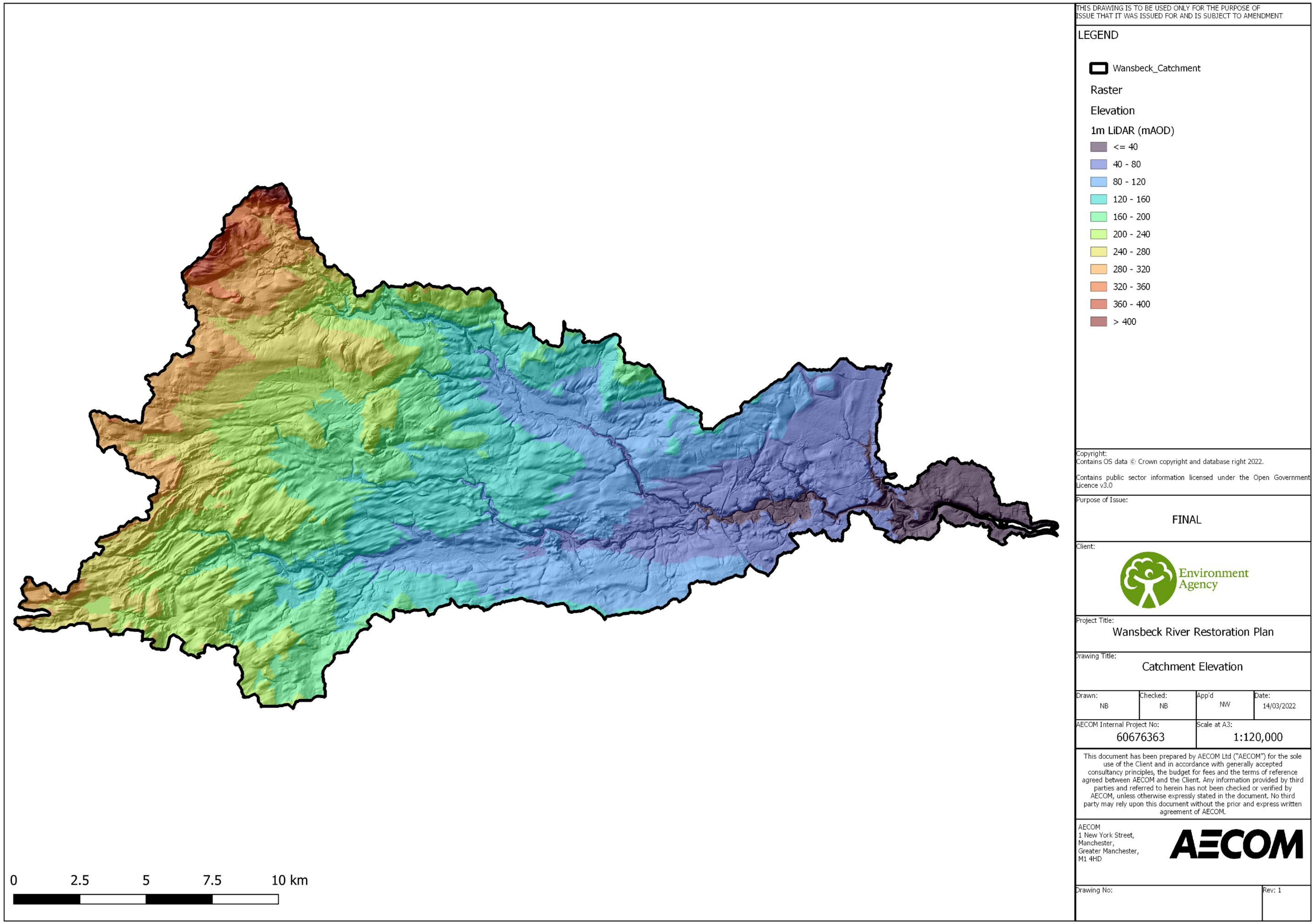


Figure 4-1 Wansbeck Catchment Elevation

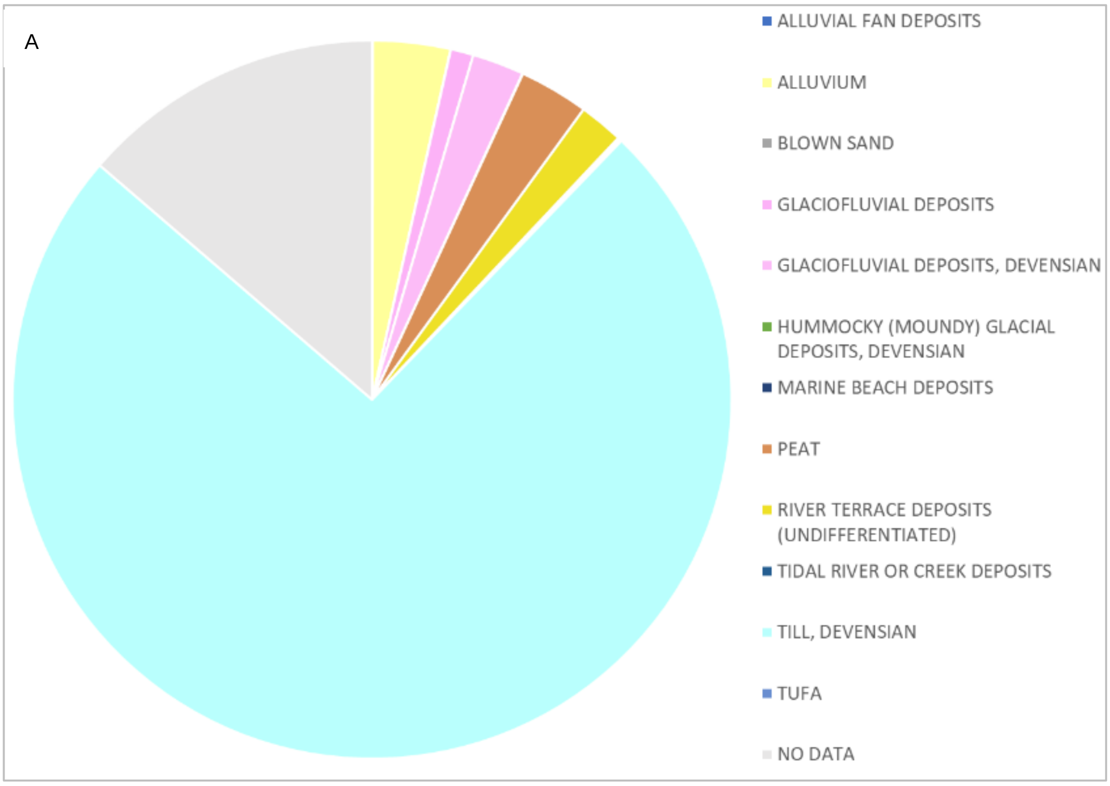
Geology and Soils

Geology

4.3 Superficial geology of the catchment is characterised by deposits that were formed during the Quaternary Period. Virtually the entire catchment is dominated by extensive diamicton till deposits that formed c. 3 million years ago. Small portions of the upper catchment are comprised of peat and river terrace deposits of sand and gravel (c. 3 million years ago), with the lower catchment being characterised by deposits of glacial sand and gravel (c. 3 million years). The southern part of the catchment is dominated by superficial deposits of alluvial clay, silt, and sand that was formed c. 2 million years ago.

4.4 Bedrock geology within the upper reaches of the Wansbeck catchment is characterised by the Yoredale formation and is dominated by limestone, argillaceous rocks, and subordinate sandstone. The sedimentary bedrock was deposited during the Carboniferous Period, c. 313 to 335 million years ago. Downstream from Sweethorpe, the Yoredale formation is interspersed with dolerite and tholeiitic basalt igneous intrusions which formed during the Carboniferous to Permian Period (c. 251 to 359 million years ago). Bedrock geology is then dominated again by the Yoredale Group until Morpeth, this section of the Wansbeck catchment is characterised by limestone, sandstone, siltstone, and mudstone. The lower reaches of the catchment are dominated by the Pennine Lower/Middle Coal Measures and the South Wales Lower/Middle Coal Measures Formation which formed c. 309 to 313 million years ago in the Carboniferous Period. These sections have sedimentary bedrock of mudstone, siltstone, sandstone, coal, ironstone, and ferricrete.

4.5 Proportions of catchment superficial and bedrock geology are provided in Figure 4-2 A and B respectively; and their distribution is shown in Figure 4-3 and Figure 4-4 respectively.



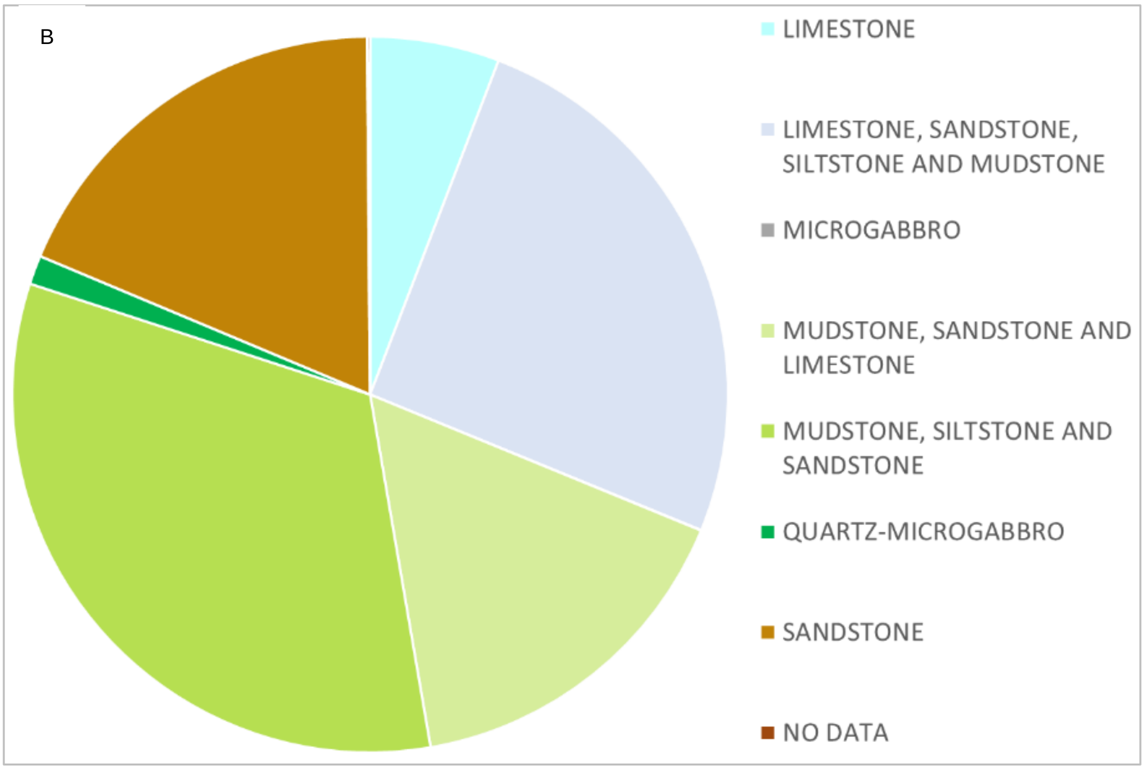


Figure 4-2 Proportions of catchment superficial geology (A) and bedrock geology (B)

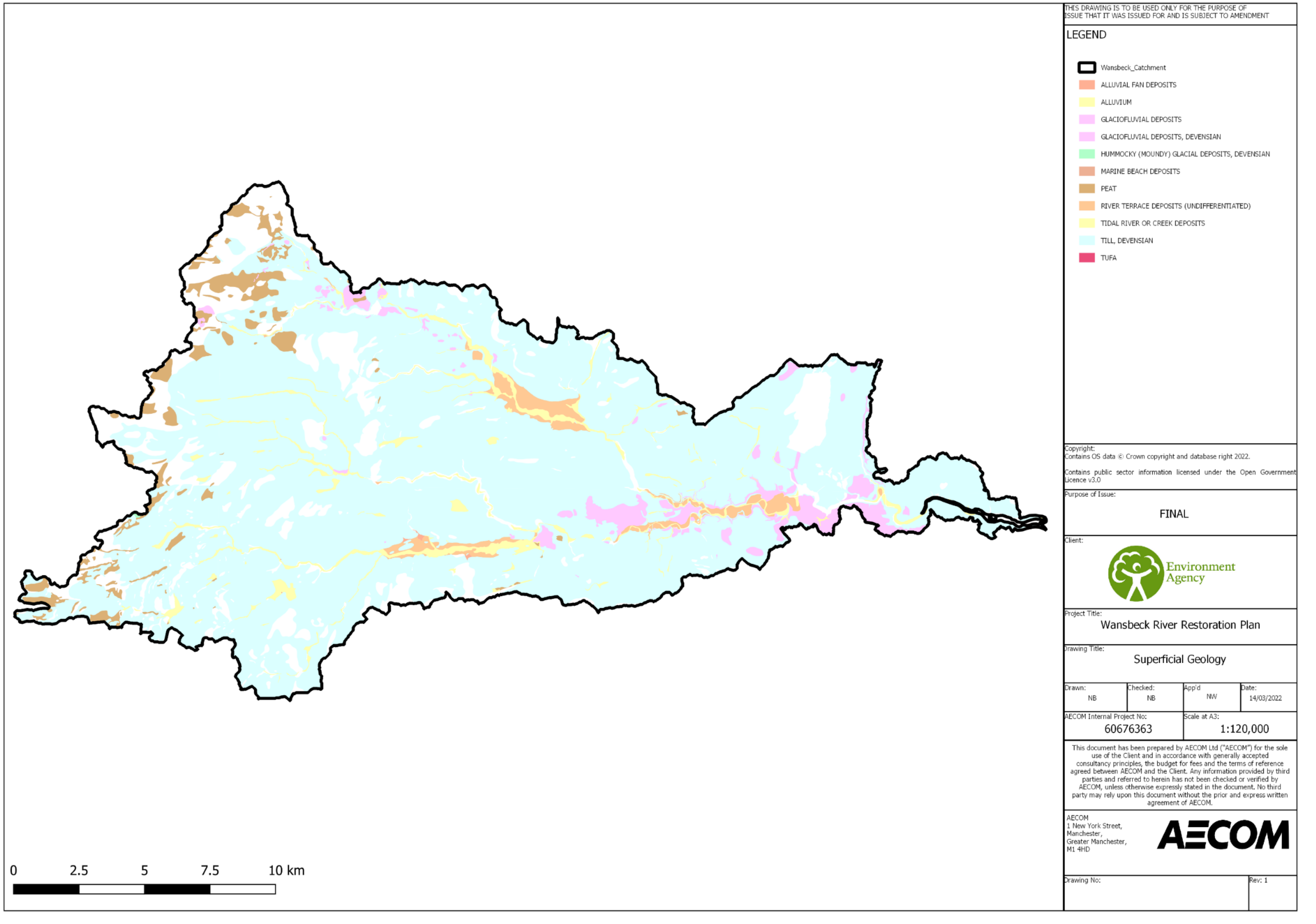


Figure 4-3 Wansbeck Catchment: superficial geology

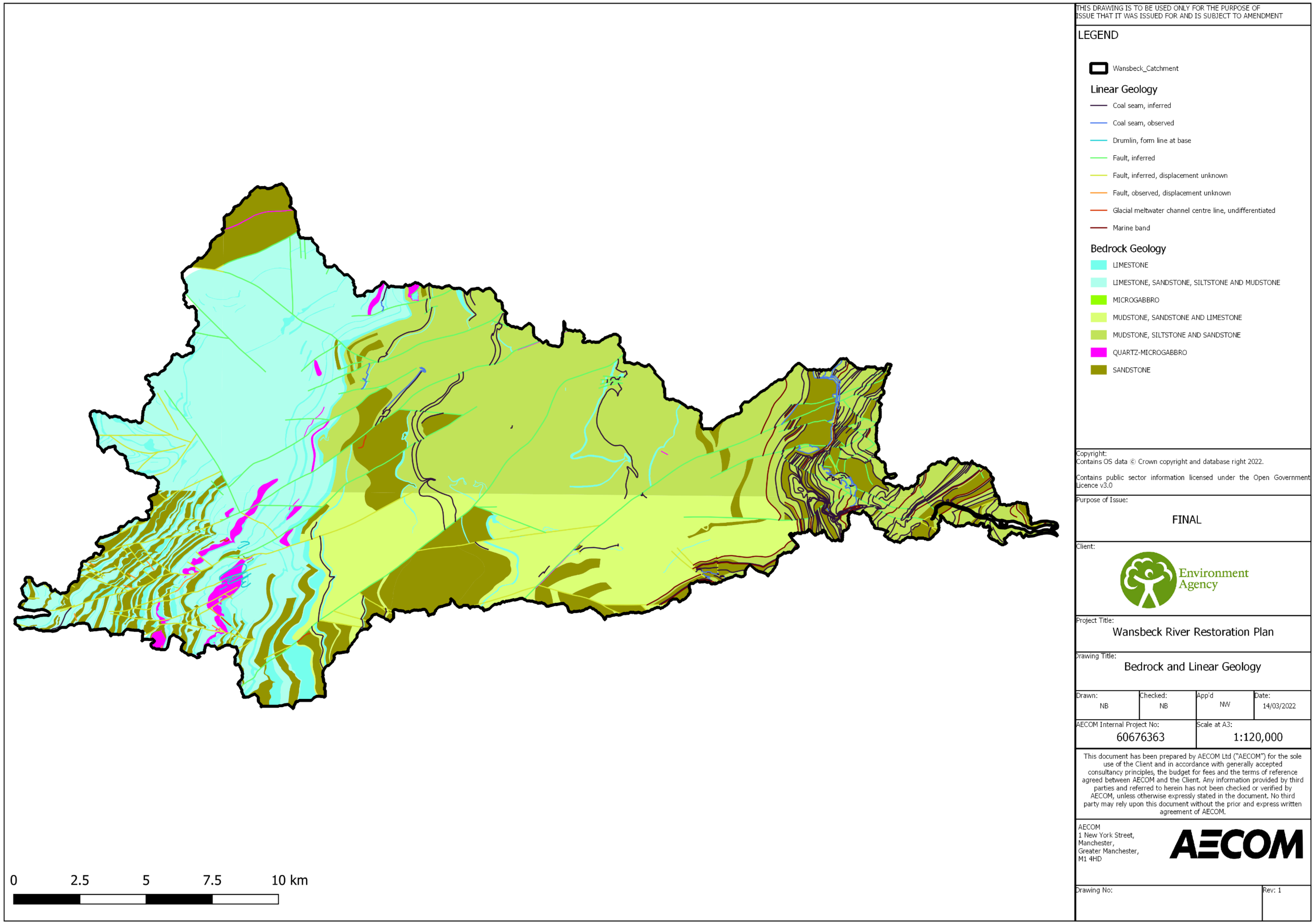


Figure 4-4 Wansbeck Catchment: bedrock and linear geology

Soils

4.6 Wansbeck catchment soils are dominated by slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils that comprise around 56% of its area. This soil type occupies the majority of lower lying areas and facilitates intensive agriculture that takes place throughout the catchment.

4.7 Upland regions are dominated by very wet and acidic soils with a peaty surface (around 20% of catchment area) that support grass and heather moorland with flush and bog communities in wetter areas; though rough grazing and coniferous plantations account for much of the land use in these areas.

4.8 River valleys are occupied variously by neutral and acid pastures, raised bog communities, base-rich pastures and deciduous woodlands and wet flood meadows with wet carr woodlands in former river meanders. These collectively make up around 9% of catchment soils.

4.9 The remaining 15% of the catchment is occupied by fragmented parcels of soil types including freely draining slightly acid but base-rich soils, naturally wet very acid sandy and loamy soils and freely draining very acid sandy and loamy soils. Proportions of catchment soil is provided in Figure 4-5 and their distribution is shown in Figure 4-6

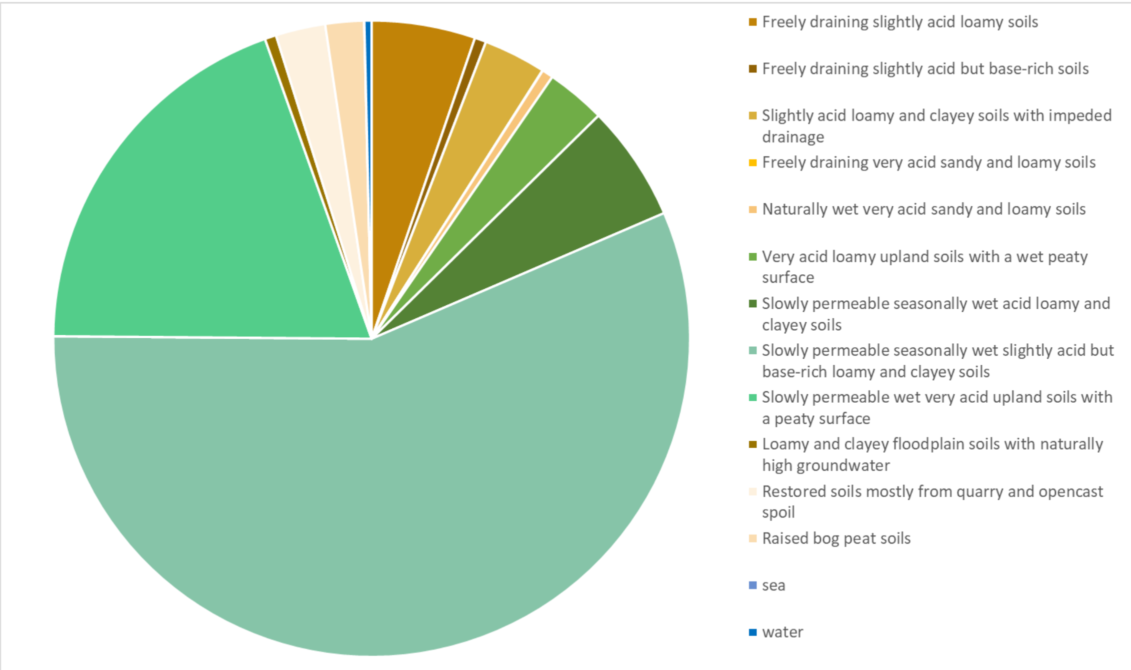


Figure 4-5 Proportions of Catchment Soils

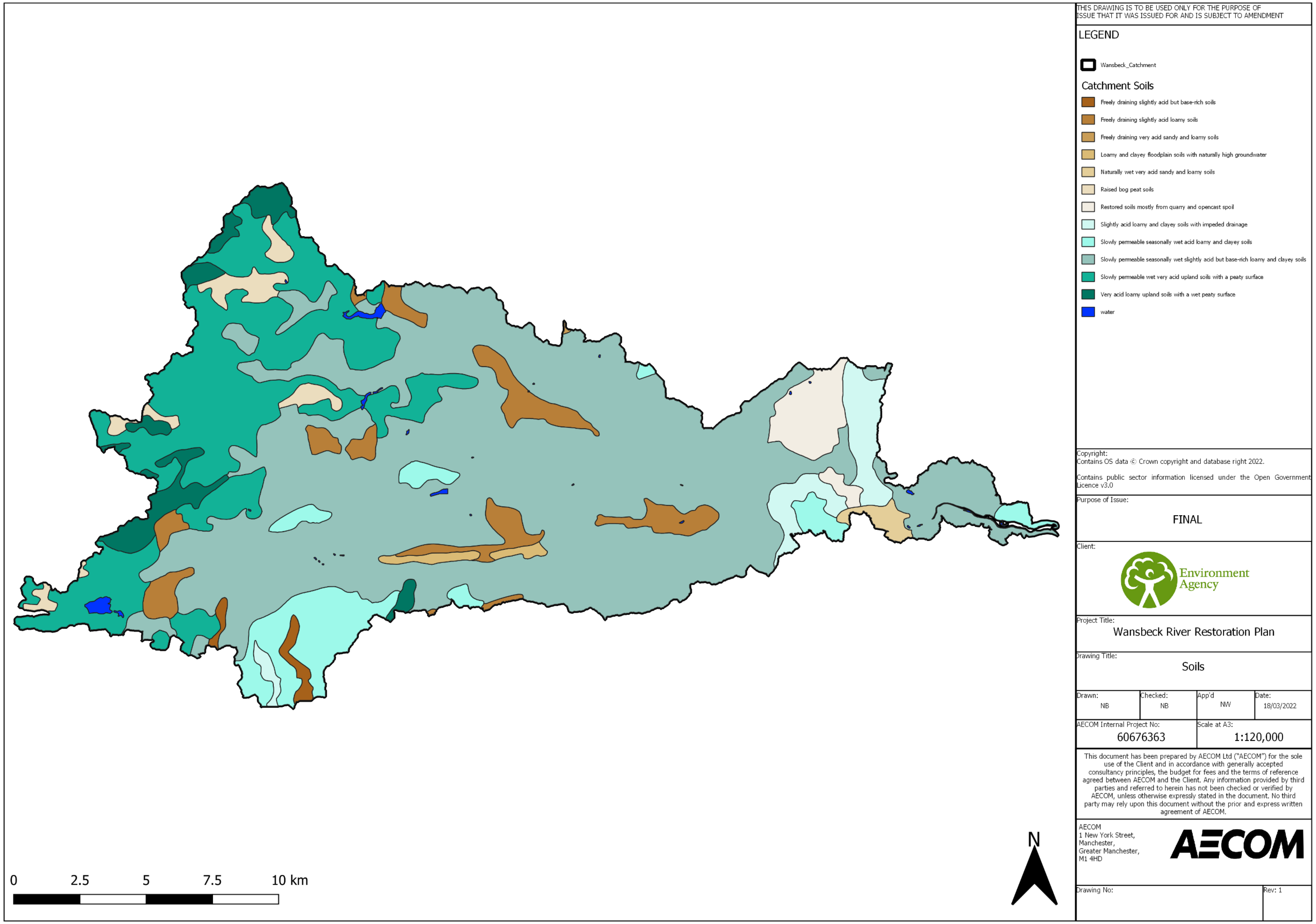


Figure 4-6 Catchment Soils

Hydrology

4.10 Catchment hydrology is driven by moderate rainfall – particularly within the upper, high elevation reaches of the catchment. Annual Average Rainfall is c. 800mm, which, coupled with the relatively low baseflow index of 0.37 and the mostly impermeable glacial till that dominates the catchment results in a flashy flood hydrograph and regular major flood events (EA, 2005). The River Wansbeck is gauged at Mitford Weir c. 2.5 km upstream of Morpeth from which a summary of data is provided in Figure 4-7 and Table 4-1.

A

B

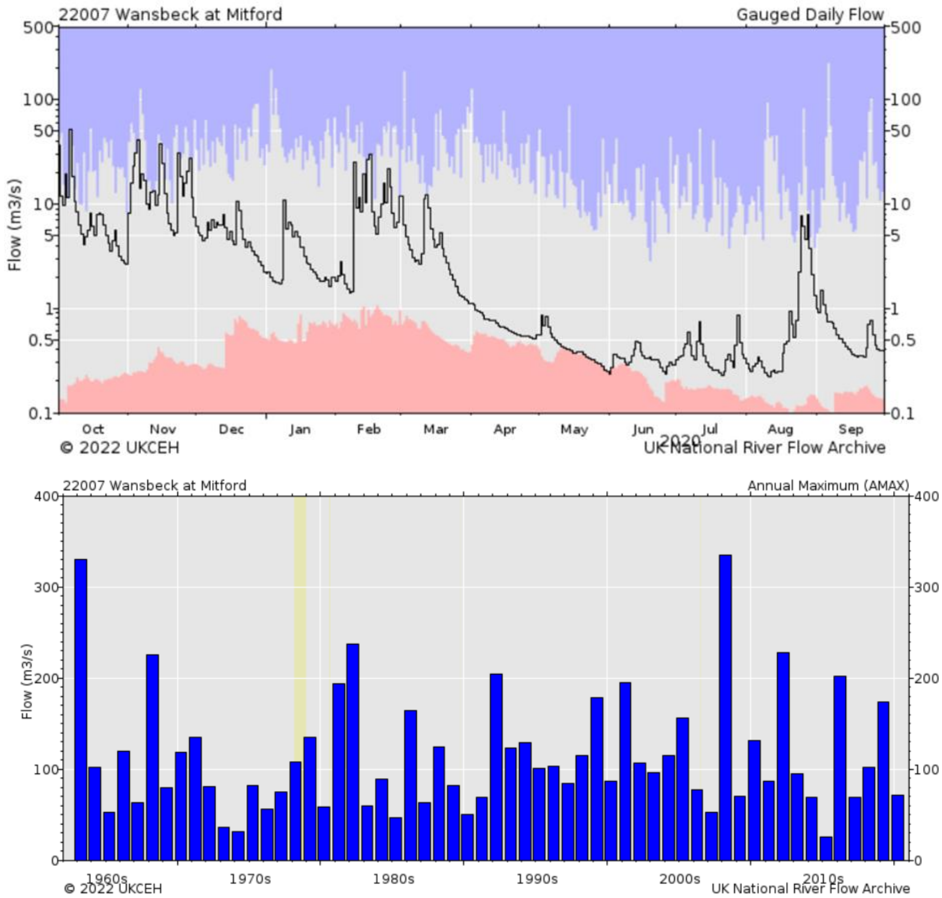


Figure 4-7 A: Gauged daily flow from 2020 within max and min flows for each day of the calendar, and B: Maximum instantaneous peak flows from the 22007 – Wansbeck at Mitford NRFA gauge provided by CEH (2022). The maximum gauged flow occurred in September 2008. The yellow shading represents periods of missing data.

Table 4-1 Summary of river flow data from the River Wansbeck at Mitford Gauge

Flow Parameter	Discharge (m^3/s)
Mean Flow	3.29
Q_{95}	0.24
Q_{70}	0.62
Q_{50}	1.32
Q_{10}	7.42
Q_{5}	11.9
Qmed[2]	98.5
Qmax	334.58

[2] The mean annual maxima flood

Land Use

4.11 Catchment land use is significantly dominated by agriculture, with arable farming and improved grassland accounting for over 60% of land use types (18.7% and 42.6% respectively). Deciduous woodland occupies around 11% of the catchment area but is generally confined to deep and steep-sided river valleys where potential for farming and land management is low. This, however, is closely followed by managed coniferous woodland which dominates the north-west corner of the catchment and accounts for over 10% of its area. Urban and sub-urban areas cover a relatively small proportion of the catchment (about 4% combined) but this is concentrated in the lowermost areas of the catchment in the urban centres of Morpeth and Ashington, though there are numerous villages and hamlets within the catchment.

4.12 Natural, or low-managed, land use types are predominately comprised of acid grassland (5.5%), heather grassland (4.5%) and heather (1.6%), with very small proportions of bog, neutral grassland and saltmarsh each occupying significantly less than 1% of catchment land use. These broadly occupy the uppermost south-west reaches of the catchment (other than saltmarsh at the eastern coastal areas), but remain interspersed with artificial land use types (coniferous plantations, improved grassland etc.)

4.13 In summary, over 75% of the catchment area has been significantly altered by anthropogenic activity – principally agricultural practices, but also water resource management and urbanisation. Areas that have remained natural or semi-natural are not conducive for farming – particularly the steeply incised river valleys in the central region of the catchment – and, therefore, have avoided degradation, though these areas are somewhat fragmented. A summary of land use proportions is provided in Figure 4-8 and the distribution of land use across the catchment is shown in Figure 4-9.

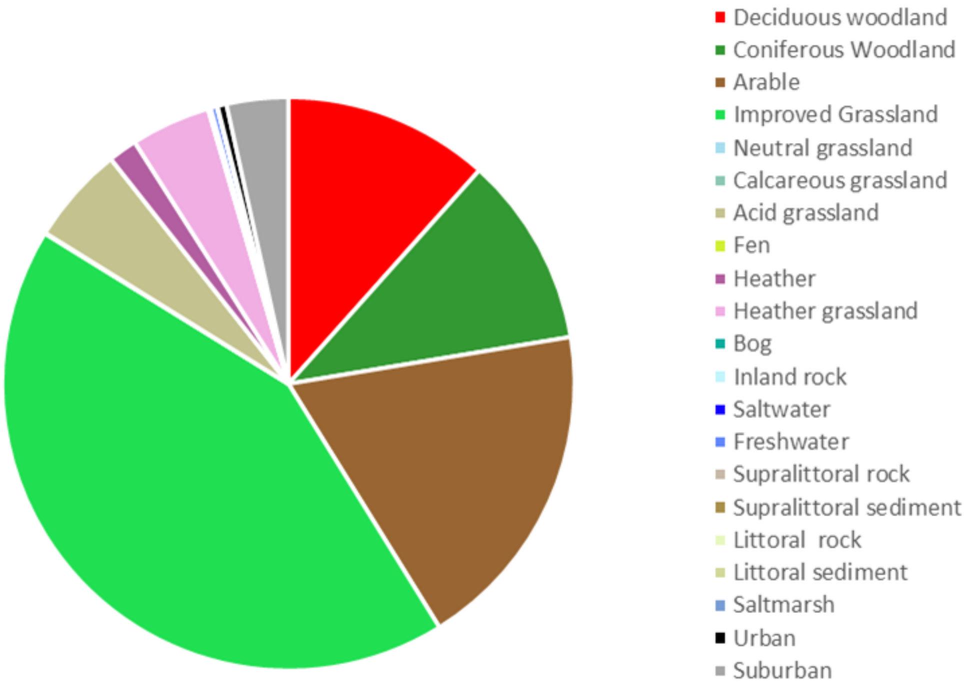


Figure 4-8 Proportions of land use types in the Wansbeck catchment.

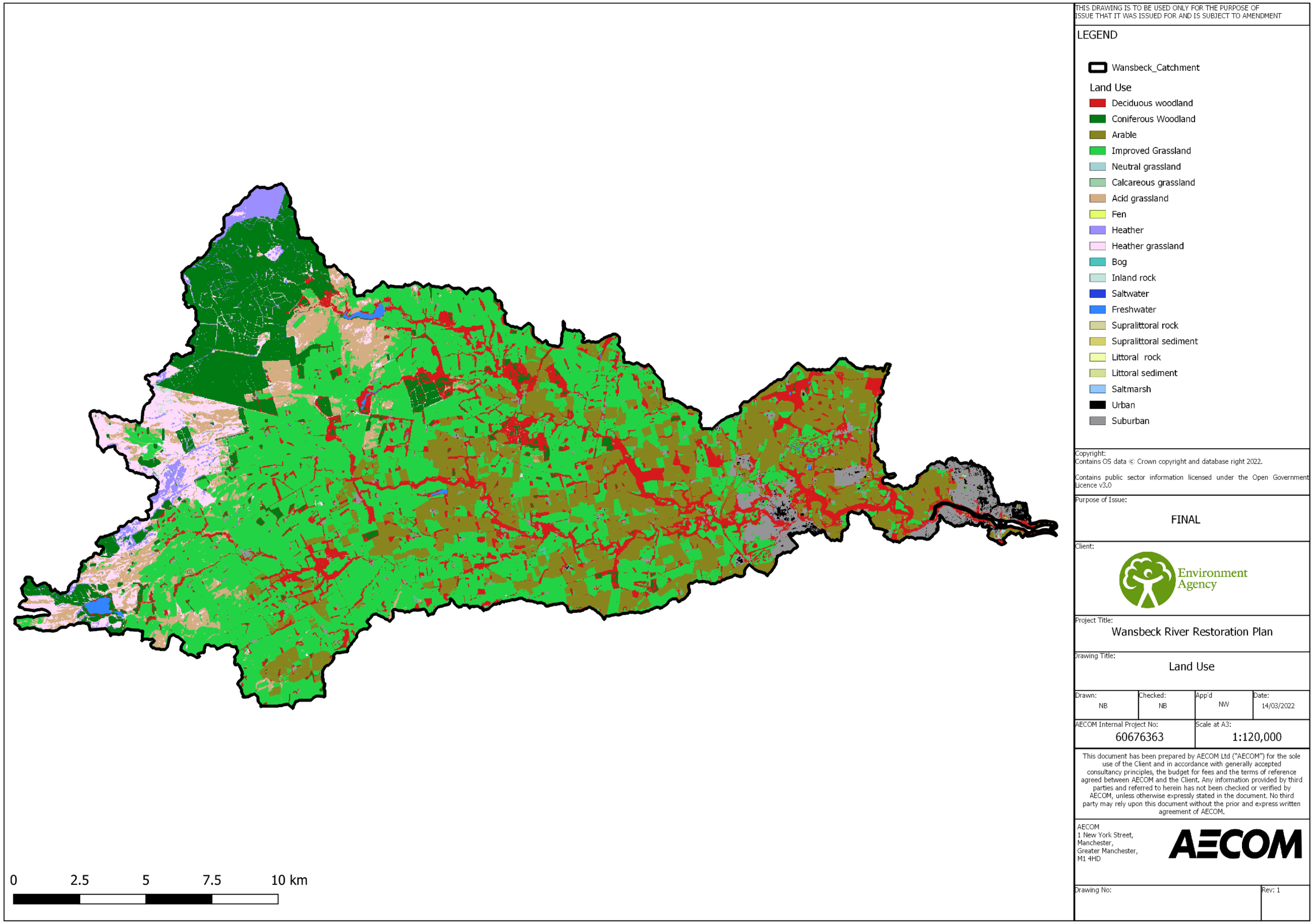


Figure 4-9 Wansbeck Catchment Land Use

WFD Status and Objectives

4.14 The Water Framework Directive is one of the major drivers for the river restoration component of this project. The Wansbeck catchment comprises 11 WFD water bodies (Figure 4-10), of which just two are presently meeting their objectives, but remain sensitive to adverse impacts derived from agriculture, the water industry, urbanisation and climate change. River restoration has been identified as crucial element for addressing some of the pressures that contribute to the overall sub-standard condition of the Wansbeck system. A summary of current WFD status is provided in Table 4-2 and a map of water bodies is shown in Table 4-2.

Table 4-2 Current WFD statuses of WFD water bodies in the Wansbeck Catchment.

Water Body	Current Ecological Status	Status Objective
Font from Source to Wansbeck	Moderate	Good by 2027
Wansbeck from Source to Ray Burn	Good	Good by 2015
Ray Burn Catchment (trib of Wansbeck)	Poor	Good by 2027
Wansbeck from Hart Burn to Font	Good	Good by 2015
Wansbeck from Ray Burn to Hart Burn	Poor	Good by 2027
Hart Burn from Delf Burn to Wansbeck	Moderate	Good by 2027
Hart Burn from Source to Delf Burn	Poor	Good by 2021
Bothal Burn Catchment (trib of Wansbeck)	Poor	Moderate by 2027
Delf Burn Catchment (trib of Hart Burn)	Poor	Good by 2027
Wansbeck from Font to Bothal Burn	Moderate	Good by 2027
Wansbeck from Bothal Burn to North Sea	Moderate	Good by 2027

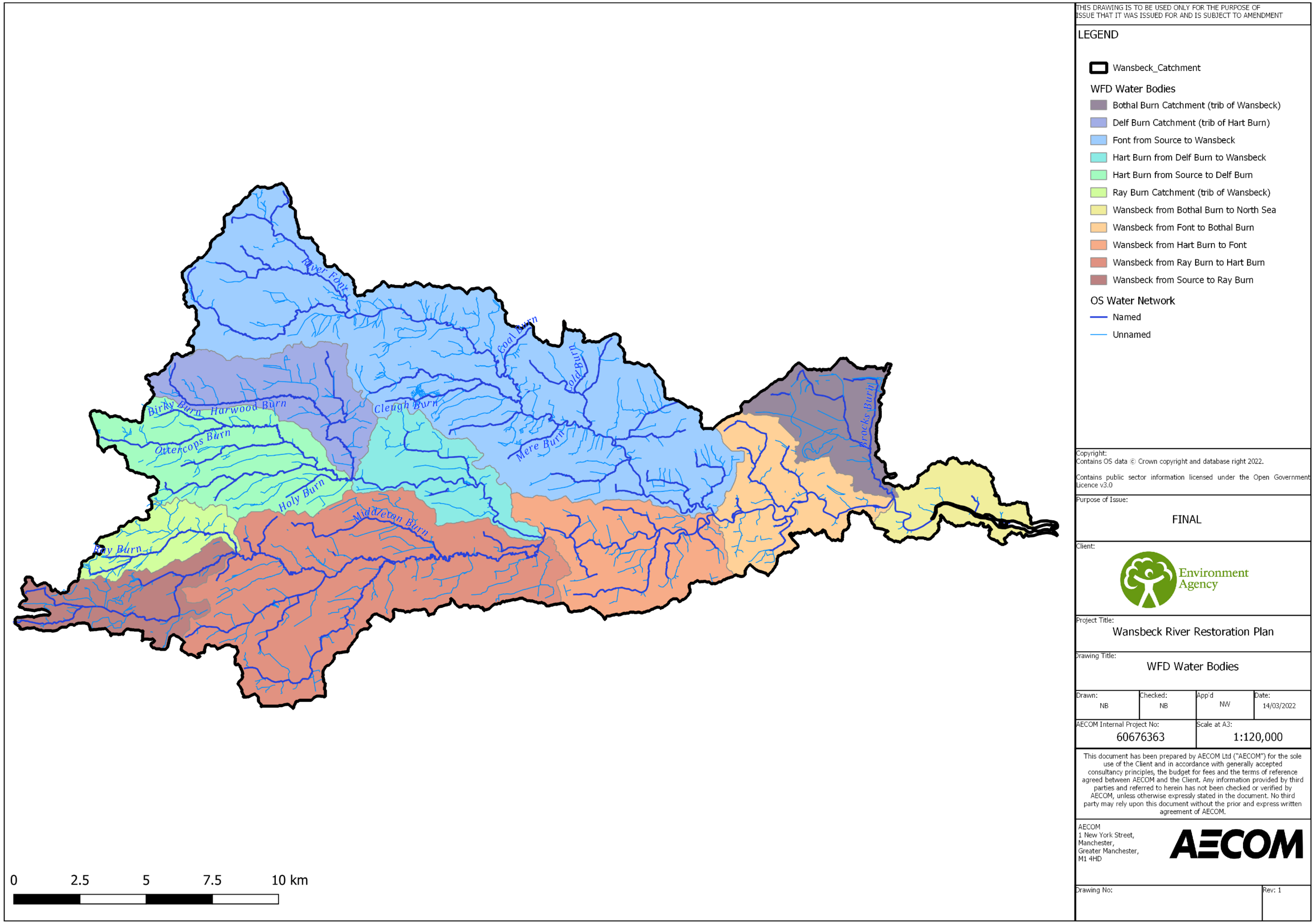


Figure 4-10 WFD Water Bodies in the Wansbeck Catchment

Areas of Constraint and Opportunity

Land use

4.15 As previously described, the Wansbeck catchment is dominated by improved grassland and arable farmland land use types, which, from an ecological perspective, are low value and thus are viable for restoration, if practicable. There are, however, parcels of high-quality habitats which should be retained and possibly expanded which are covered in detail the corresponding Habitat Restoration and Creation Plan produced by AECOM in tandem with this report, which presents locations of existing primary habitats. In particular, deeply incised river valleys in the central and lower reaches of the catchment have largely avoided direct anthropogenic pressures and support strips of deciduous woodland that broadly follow the course of river corridors: these areas are, therefore, discounted from the river restoration longlist because they are assumed to support better quality habitat than areas that are intensively cultivated or able to support livestock.

4.16 Urban and sub-urban areas are scoped out for river restoration due to the difficulties of delivering restoration within built-up areas, which are often very constrained and carry significant risk. Similarly, linear infrastructure features – such as roads and railways – generally present a constraint to river restoration; therefore, a 20m buffer around such features has been applied, within which any enhancements are scoped out. A combined map of areas of constraint and opportunity are shown in Figure 4-11.

Topography

4.17 The character of the Wansbeck catchment is strongly influenced by its topography. Deep river valleys incised into thick glacio-fluvial deposits present limited river restoration opportunities because they are naturally confined, difficult to access, and thus have avoided significant direct impacts from agriculture or urbanisation. Conversely, there are areas where extensive alluvial plains, that once probably accommodated dynamic actively meandering or wandering river-floodplain systems, have been drastically impacted by farming precisely because they are easy to manage, cultivate and build upon. These flat, extensive and unconfined valley bottoms are conducive to river restoration because they provide scope to incorporate significant enhancement with relatively little effort and deliver multiple benefits beyond restoring in-channel processes; for example, positive contribution to lowering flood risk, added amenity value and restoration of floodplain habitat.

4.18 Steep-sided (>10%) valleys that potentially present a constraint to river restoration, and expansive floodplain areas that potentially present restoration opportunities within the Wansbeck catchment are compared in Figure 4-12.

Ecology

4.19 The Habitat Network Modelling undertaken by AECOM and presented in the Wansbeck Habitat Creation Plan (AECOM, 2022) has revealed areas of the catchment that are conducive to expansion and restoration of existing primary habitats. Areas that are ‘blank spaces’ in the plan provided in Figure 4-13 are potential habitat links, where restored river habitat would provide corridors between restored terrestrial habitats, or further enhance the riverine element of land parcels that have been identified for primary habitat expansion. This approach unifies the riverine and terrestrial components of the catchment landscape.

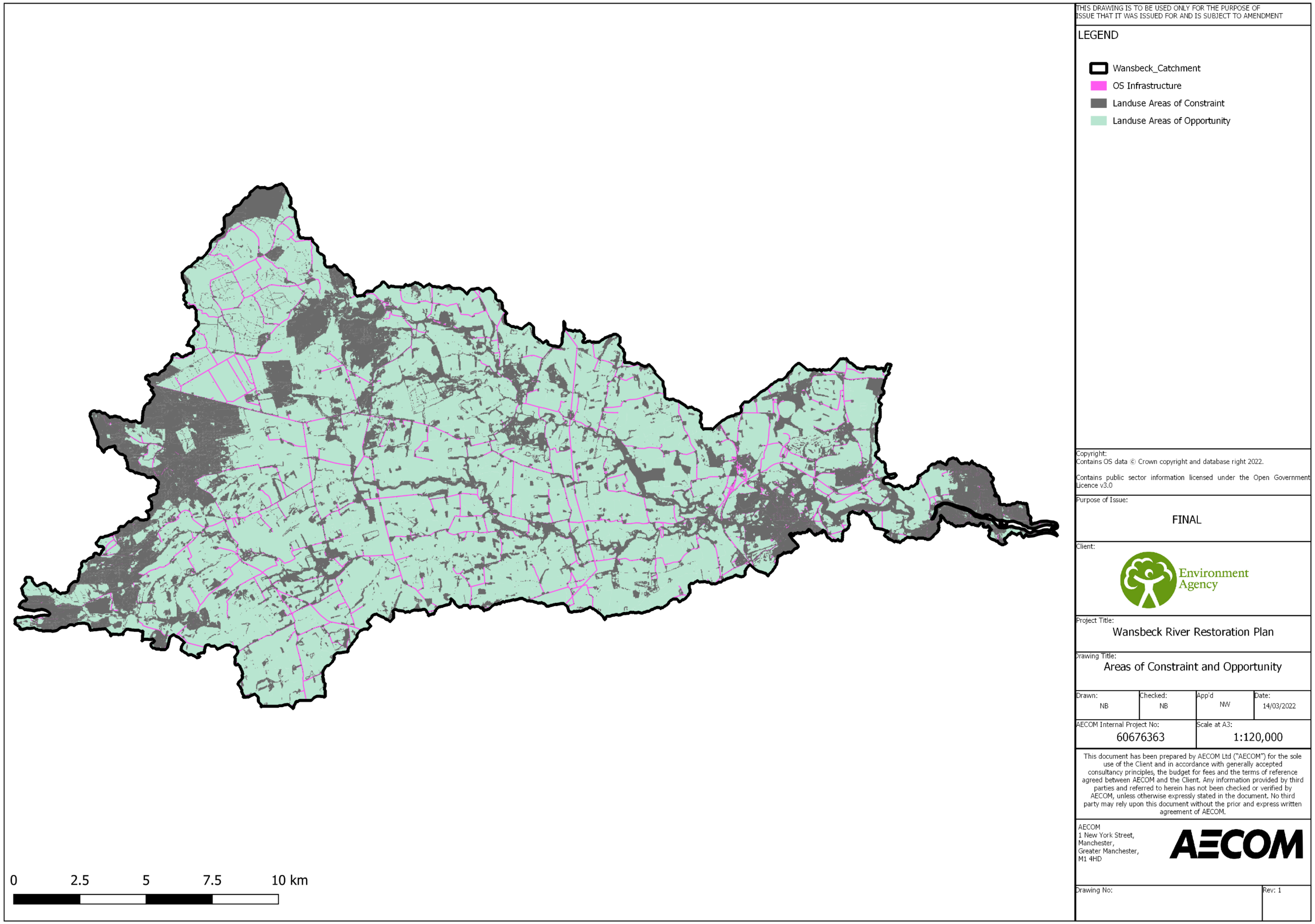


Figure 4-11 Area of constraint and opportunity

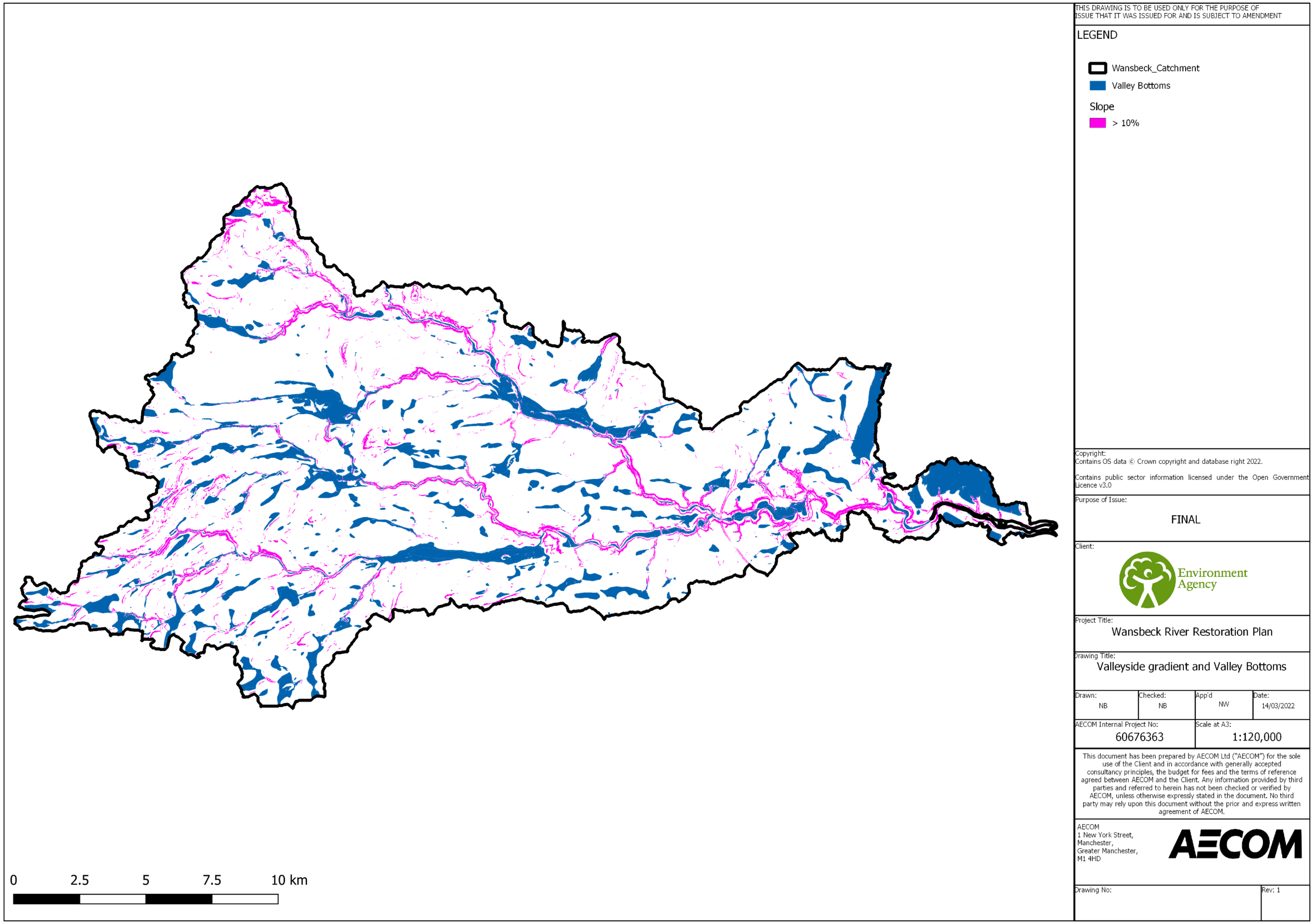


Figure 4-12 Valley bottoms and steeped-sided valleys in the Wansbeck catchment.

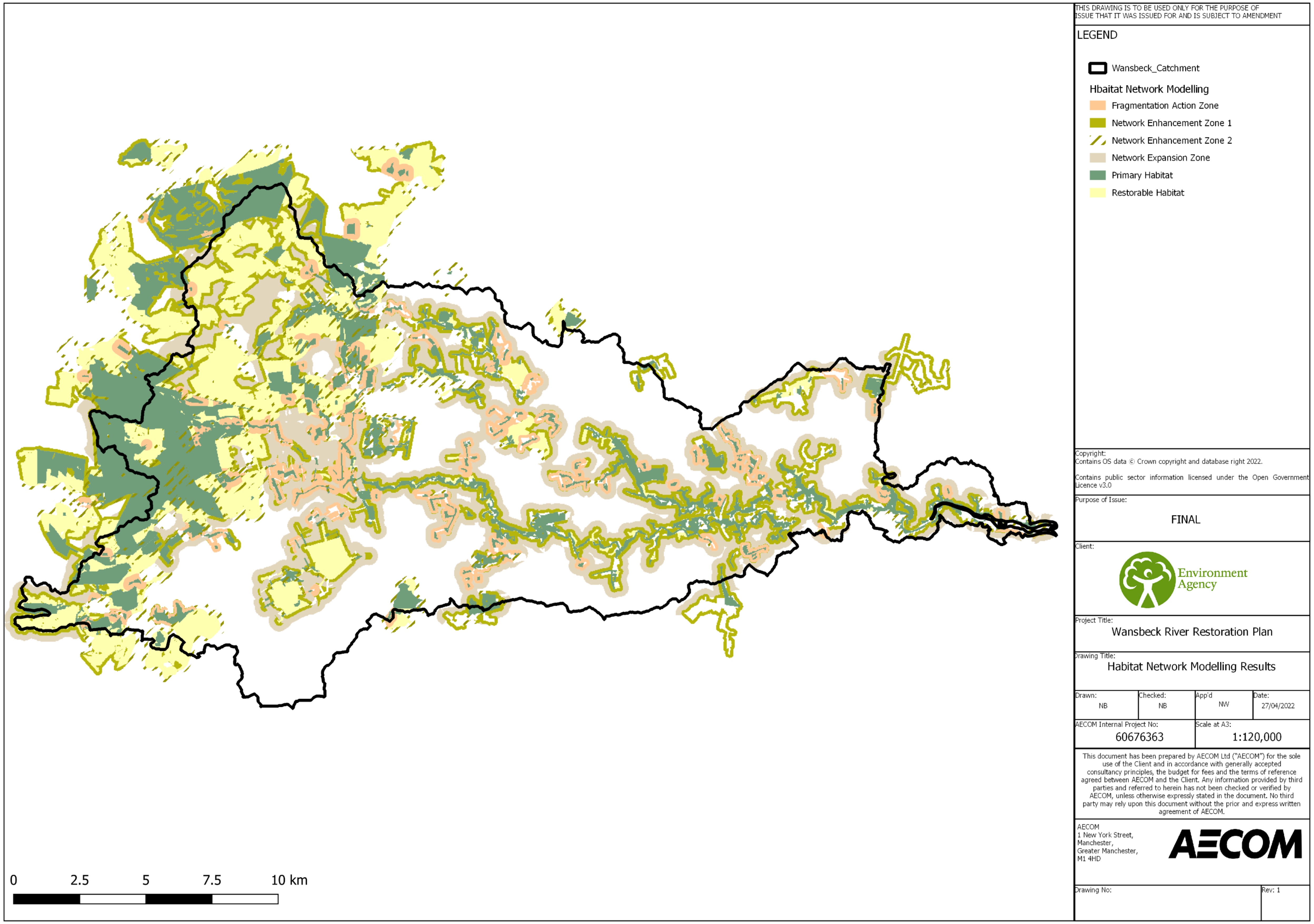


Figure 4-13 Combined Habitat Network Modelling Results.

Summary

4.20 The Wansbeck catchment has been heavily defined by both natural and anthropogenic influences that have given rise to the character of watercourses that drain it. Sequences of glaciation and de-glaciation generated a virtually catchment-wide layer of till deposits, into which the river system has eroded deeply incised valleys interspersed with well-developed expansive alluvial floodplains flanked by relic terrace sequences. These deposits have been extensively re-worked by riverine processes, such that successions of river terraces are readily observable in the geological and topographic record in places.

4.21 Contemporary land use changes, however, have completely altered the overall character of the catchment, with widespread de-forestation, land management and intensive agriculture; coal mining; reservoir construction; urbanisation; and coniferous plantation development having occurred throughout the last several centuries. These industries, in combination, have exerted significant pressures on the surface water network, such that the majority of WFD water bodies are presently failing their legislative objectives.

4.22 However, where these pressures exist, there is often an abundance of potential opportunities to restore rivers and their floodplains; though there are areas that are more conducive to restoration than others, while some reaches, in particular those that flow through incised valleys, have largely avoided significant impacts and thus are low priority. The following section presents a catchment-wide longlist of river restoration opportunities that are appropriate for their geographical location, proportional to the types of existing pressures, and account for any high-level constraints that may impede delivery of restoration.

5. Outline Restoration Plan

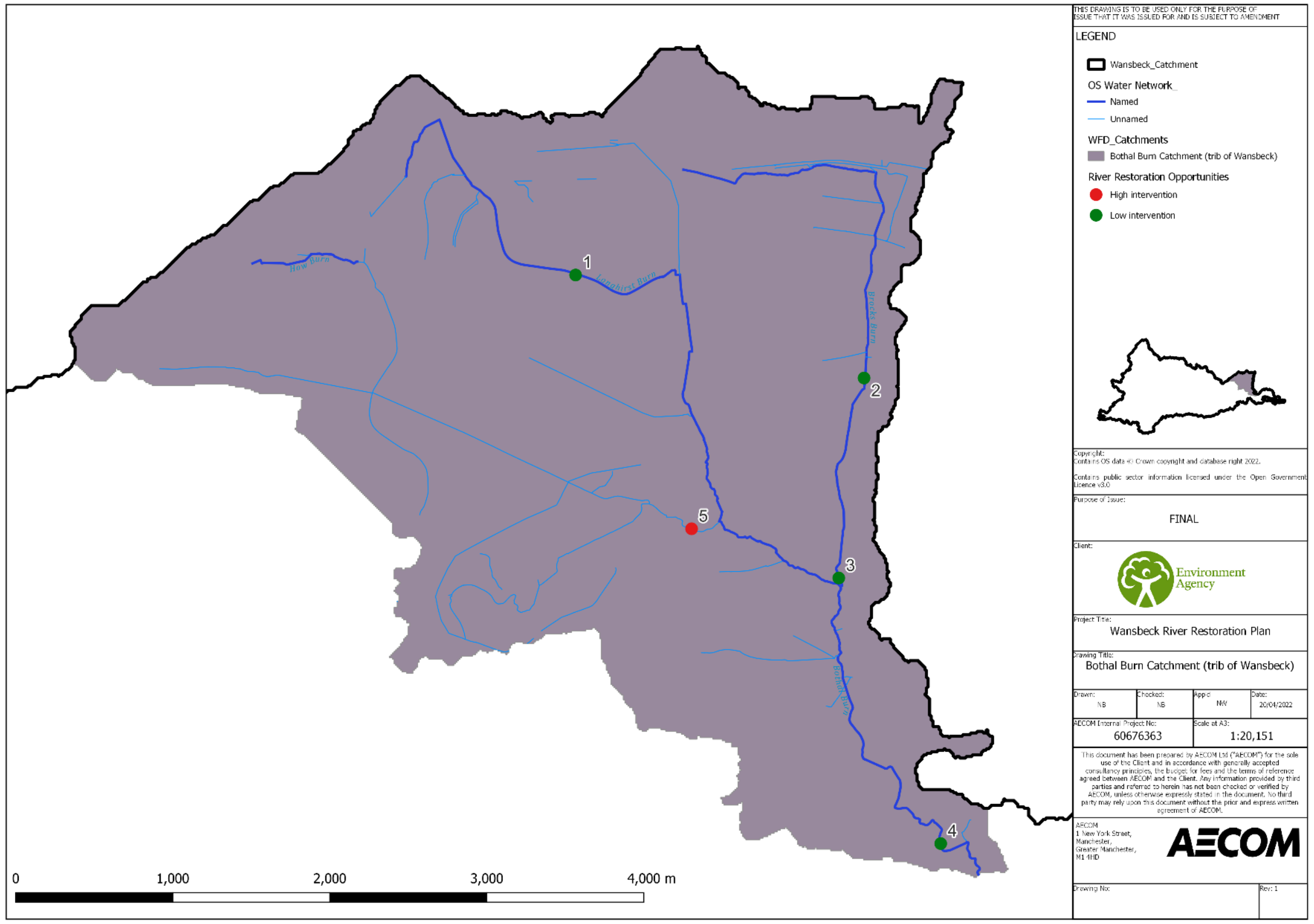
Long list of Restoration Options

5.1 The long list of restoration opportunities has been broken down by WFD water body, each of which is provided in the following section. Reasons for Not Achieving Good (RNAG) are provided for each water body in addition to current status, status objective, and hydromorphological designation. Opportunities were identified based on the desk-based analyses of the catchment and are classified as either low intervention, medium intervention, and high intervention, depending on the identified potential options, examples of which are provided in Table 5-1.

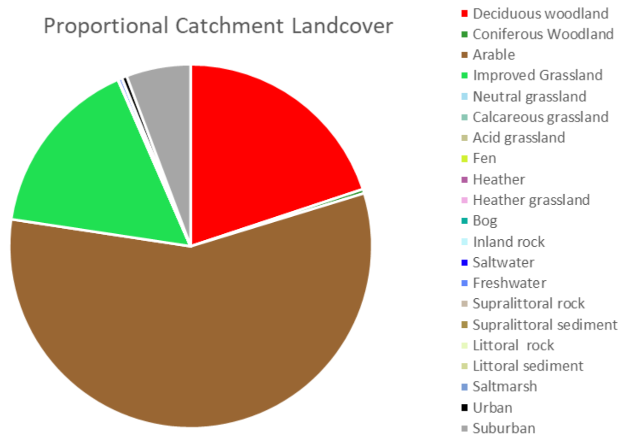
Table 5-1 Examples of low, medium and high intervention river restoration measures.

Level of intervention	Example of measures
Low	• Riparian buffer strips • Strategic Fencing • Introduce woody habitat
Medium	• Green-engineered erosion protection (e.g., willow spiling) • Grip/channel blocking • Wetland creation • Floodplain re-connection
High	• Remove structure • “Daylighting” culverted channels • Re-meandering • Channel diversion

Bothel Burn Catchment (trib of Wansbeck)



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Longhirst Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
2	Brocks Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
3	Brocks Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
4	Bothal Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
5	Longhirst Burn	Remove Structure	High intervention



Current WFD Status: Poor

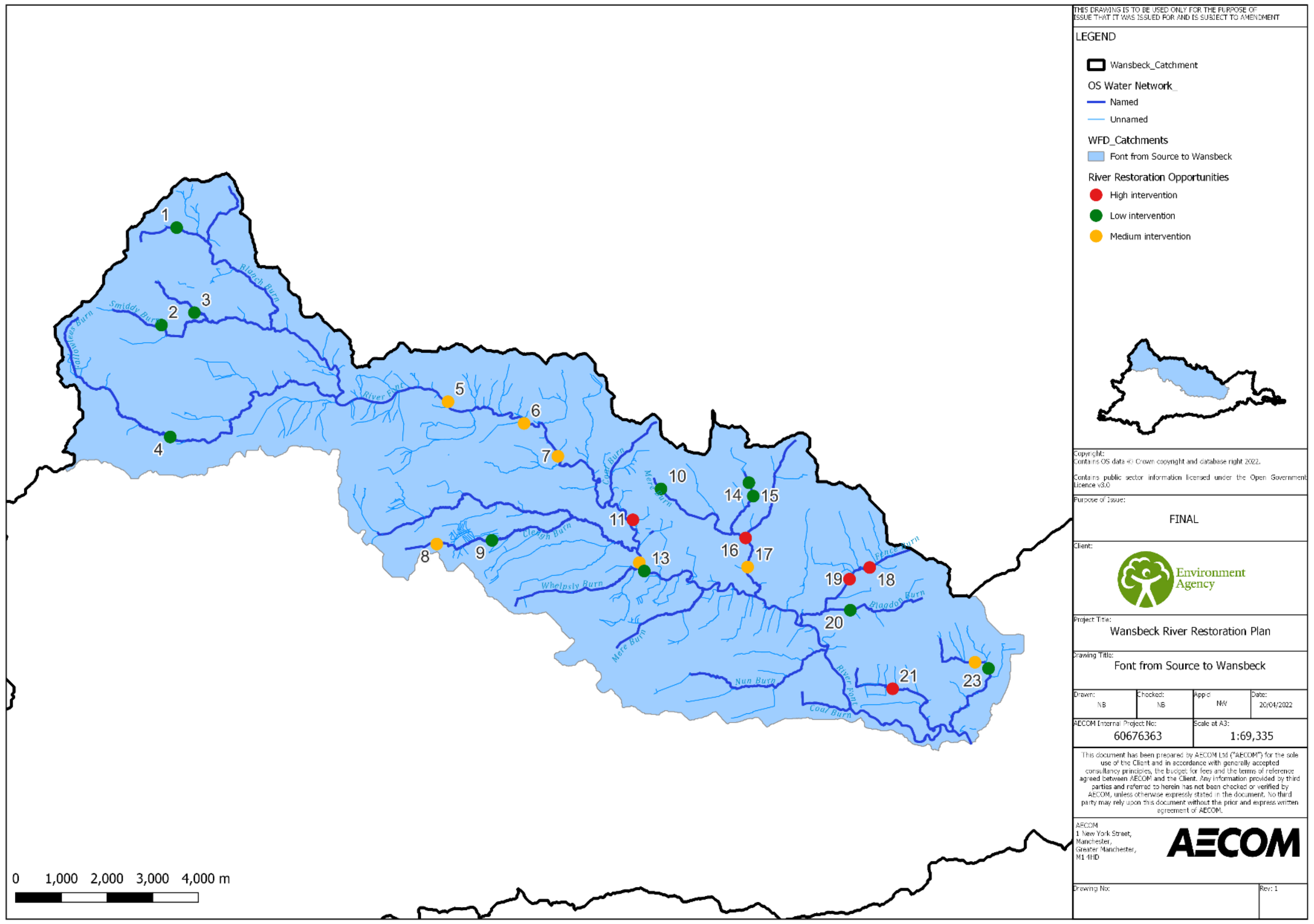
WFD Status Objective: Good by 2027

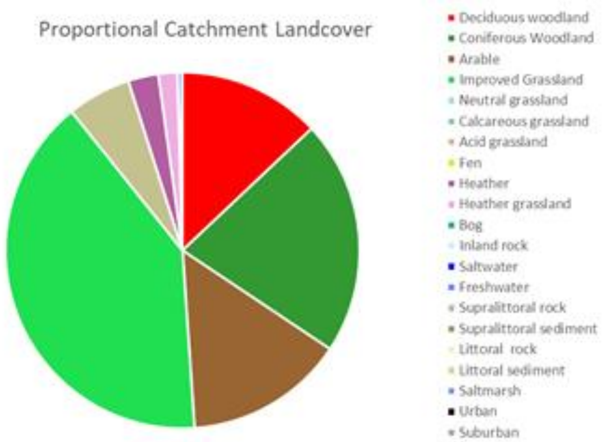
not designated as A/HMWB

RNGA:

- **Pollution from rural areas (Agriculture and land management)**
- **Pollution from waste water (Water industry, Domestic general public)**
- **Pollution from towns, cities and transport (Water Industry)**

Font from Source to Wansbeck





Current WFD Status: Poor

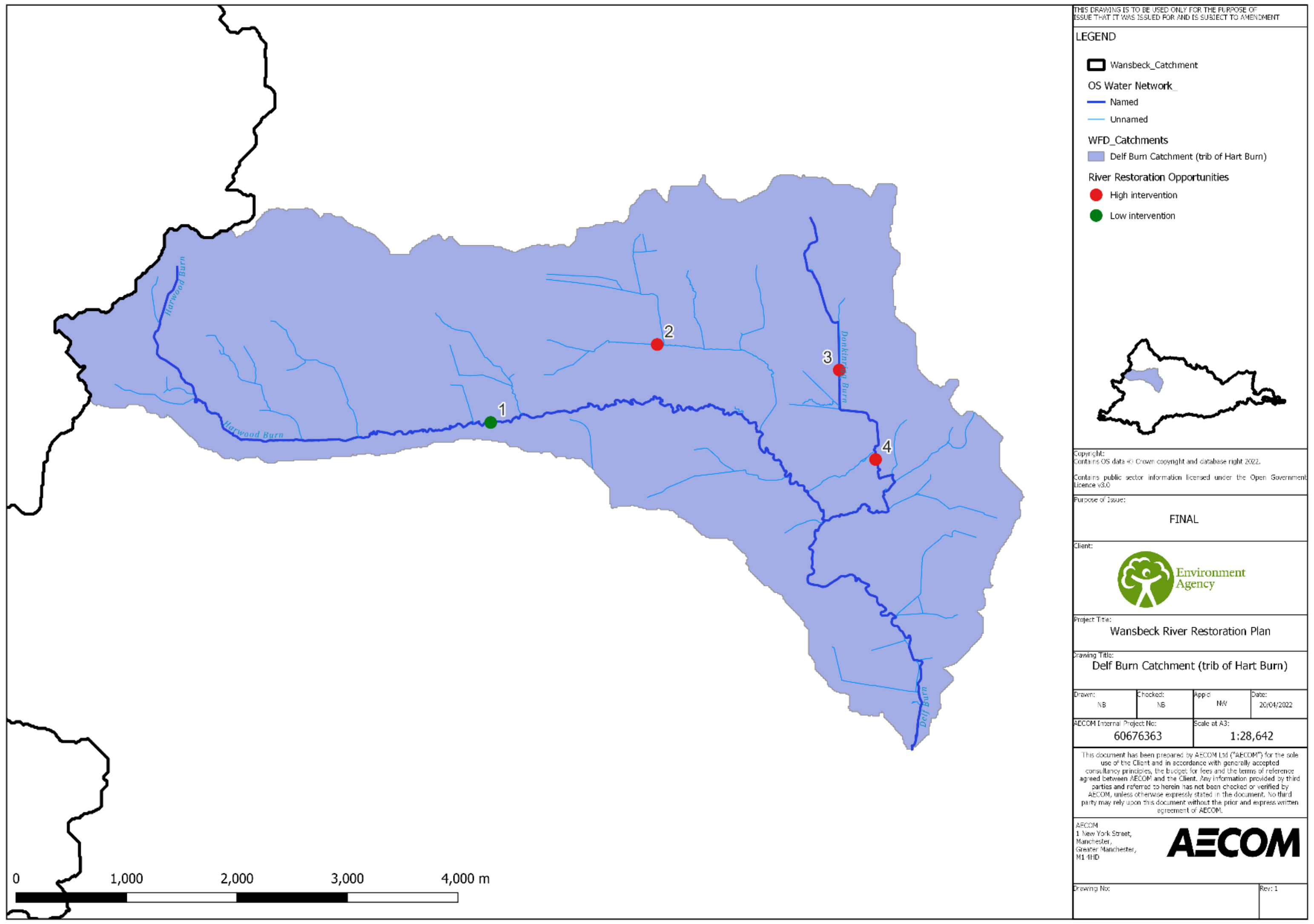
WFD Status Objective: Good by 2027

Heavily Modified

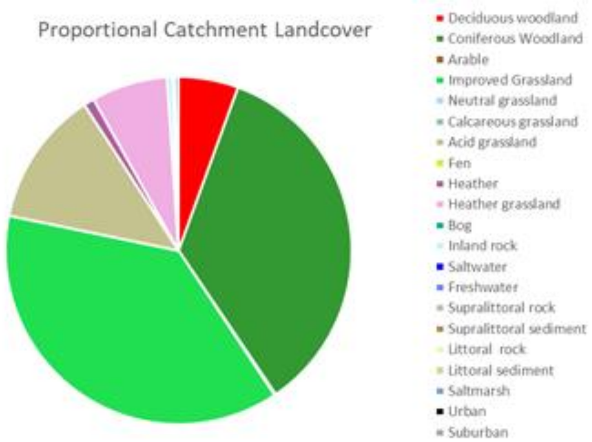
RNGA:
- **Changes to the natural flow and level of water (Water Industry)**

Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Chartner Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
2	Smiddy Burn	Introduce Woody Habitat, Establish riparian buffer strips, Strategic fencing	Low intervention
3	Newbiggin Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
4	Fallowlees Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
5	River Font	Reconnect Floodplain, Create floodplain wetland	Medium intervention
6	River Font	Reconnect Floodplain, Create floodplain wetland	Medium intervention
7	River Font	Reconnect Floodplain, Create floodplain wetland	Medium intervention
8	Cleugh Burn	Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips, Strategic fencing	Medium intervention
9	Cleugh Burn	Strategic fencing, Establish riparian buffer strips	Low intervention
10	Mere Burn	Strategic fencing, Establish riparian buffer strips	Low intervention
11	River Font	Remove Structure	High intervention
12	River Font	Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips, Strategic fencing	Medium intervention
13	River Font	Establish riparian buffer strips, Strategic fencing	Low intervention
14	Cold Burn	Strategic Fencing	Low intervention
15	Cold Burn	Manage livestock access to stream, Establish riparian buffer strips, Strategic fencing	Low intervention
16	Cowclose Burn	Remove Structure	High intervention
17	Cowclose Burn	Eliminate fine sediment sources, Manage livestock access to stream, Establish riparian buffer strips, Strategic fencing, Green erosion protection/prevention	Medium intervention
18	Fence Burn	Establish riparian buffer strips, Strategic fencing, Daylighting, Remove Structure, Vary bed topology, Re-meander, Enhance Sinuosity	High intervention
19	Fence Burn	Establish riparian buffer strips, Strategic fencing, Daylighting, Remove Structure, Vary bed topology, Re-meander, Enhance Sinuosity	High intervention
20	Blagdon Burn	Establish Riparian Buffer strips, Strategic Fencing	Low intervention
21	Harry's Burn	Establish riparian buffer strips, Strategic fencing, Daylighting, Remove Structure	High intervention
22	Benridge Burn	Eliminate fine sediment sources, Manage livestock access to stream, Establish riparian buffer strips, Strategic fencing, Green erosion protection/prevention,	Medium intervention
23	Benridge Burn	Establish riparian buffer strips, Strategic fencing	Low intervention

Delf Burn Catchment (trib of Hart Burn)



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Harwood Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
2	Harwood Burn	Block ditches and drains (grips), Reconnect Floodplain, Allow development of swamp and pond habitat, Establish riparian buffer strips, Strategic fencing	High intervention
3	Donkinrigg Burn	Enhance Sinuosity, Restore to former course, Re-meander, Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips, Allow development of grazing marsh/priority habitat,	High intervention
4	Donkinrigg Burn	Enhance Sinuosity, Restore to former course, Re-meander, Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips, Allow development of grazing marsh/priority habitat,	High intervention



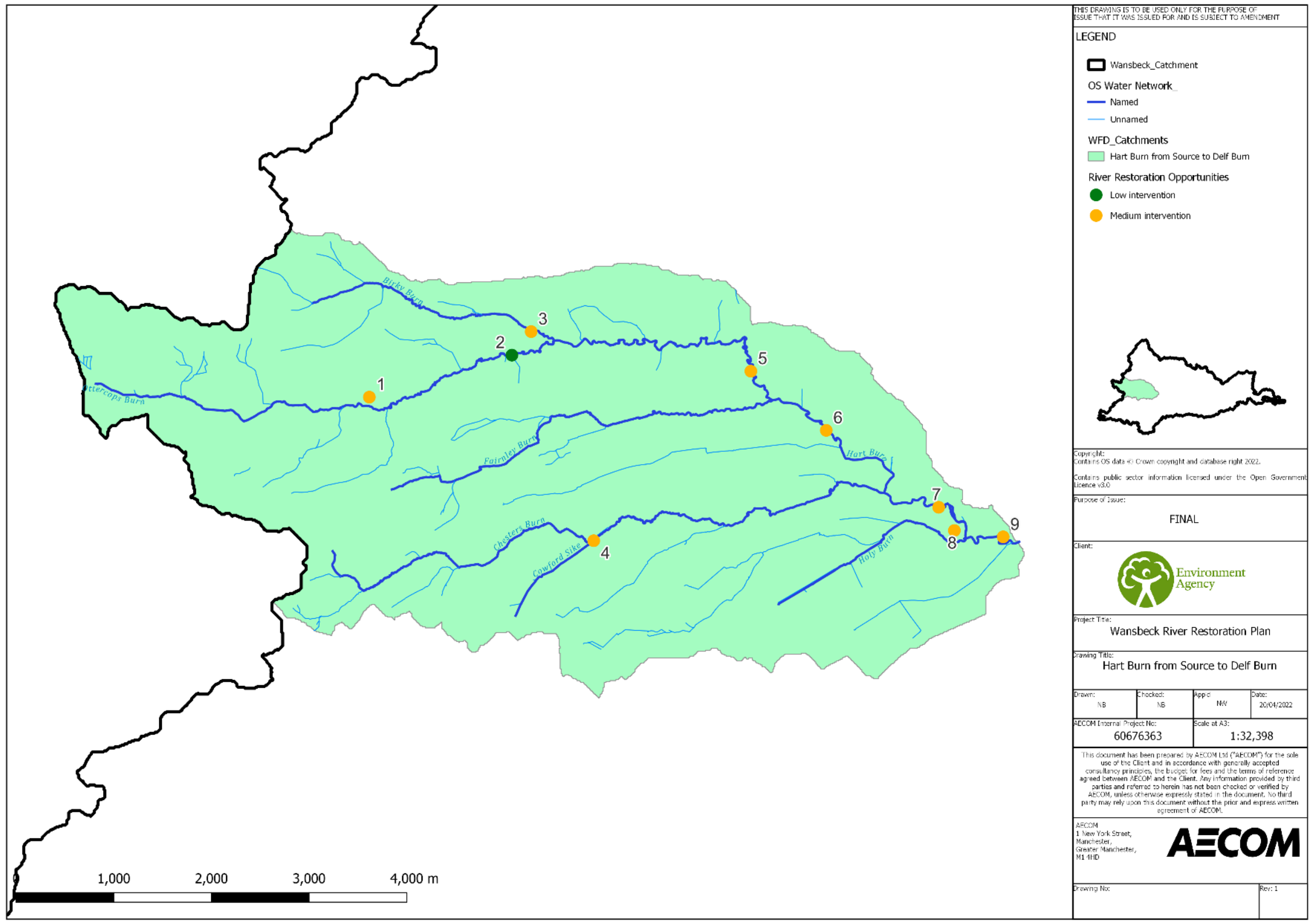
Current WFD Status: Moderate

WFD Status Objective: Good by 2027

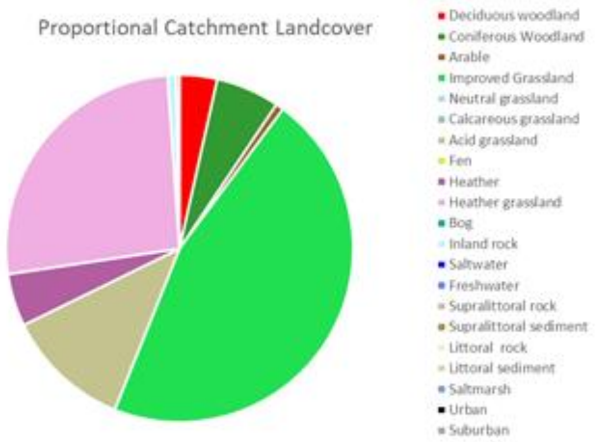
not designated as A/HMWB

RNGA:
- **Pollution from rural areas (Agriculture and land management)**

Hart Burn from Source to Delf Burn



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Ottercops Burn	Block ditches and drains (grips), Reconnect Floodplain, Allow development of swamp and pond habitat	Medium intervention
2	Ottercops Burn	Establish riparian buffer strips, Introduce Woody Habitat, Strategic fencing	Low intervention
3	Birky Burn	Block ditches and drains (grips), Reconnect Floodplain, Allow development of swamp and pond habitat	Medium intervention
4	Cowford Sike	Block ditches and drains (grips), Reconnect Floodplain, Allow development of swamp and pond habitat	Medium intervention
5	Hart Burn	Create floodplain wetland, Reconnect Floodplain, Establish riparian buffer strips, Strategic fencing	Medium intervention
6	Hart Burn	Create floodplain wetland, Reconnect Floodplain, Establish riparian buffer strips, Strategic fencing	Medium intervention
7	Hart Burn	Create floodplain wetland, Reconnect Floodplain, Establish riparian buffer strips, Strategic fencing	Medium intervention
8	Hart Burn	Create floodplain wetland, Reconnect Floodplain, Establish riparian buffer strips, Strategic fencing	Medium intervention
9	Hart Burn	Establish riparian buffer strips, Strategic fencing, Green erosion protection/prevention, Manage livestock access to stream, Eliminate fine sediment sources	Medium intervention



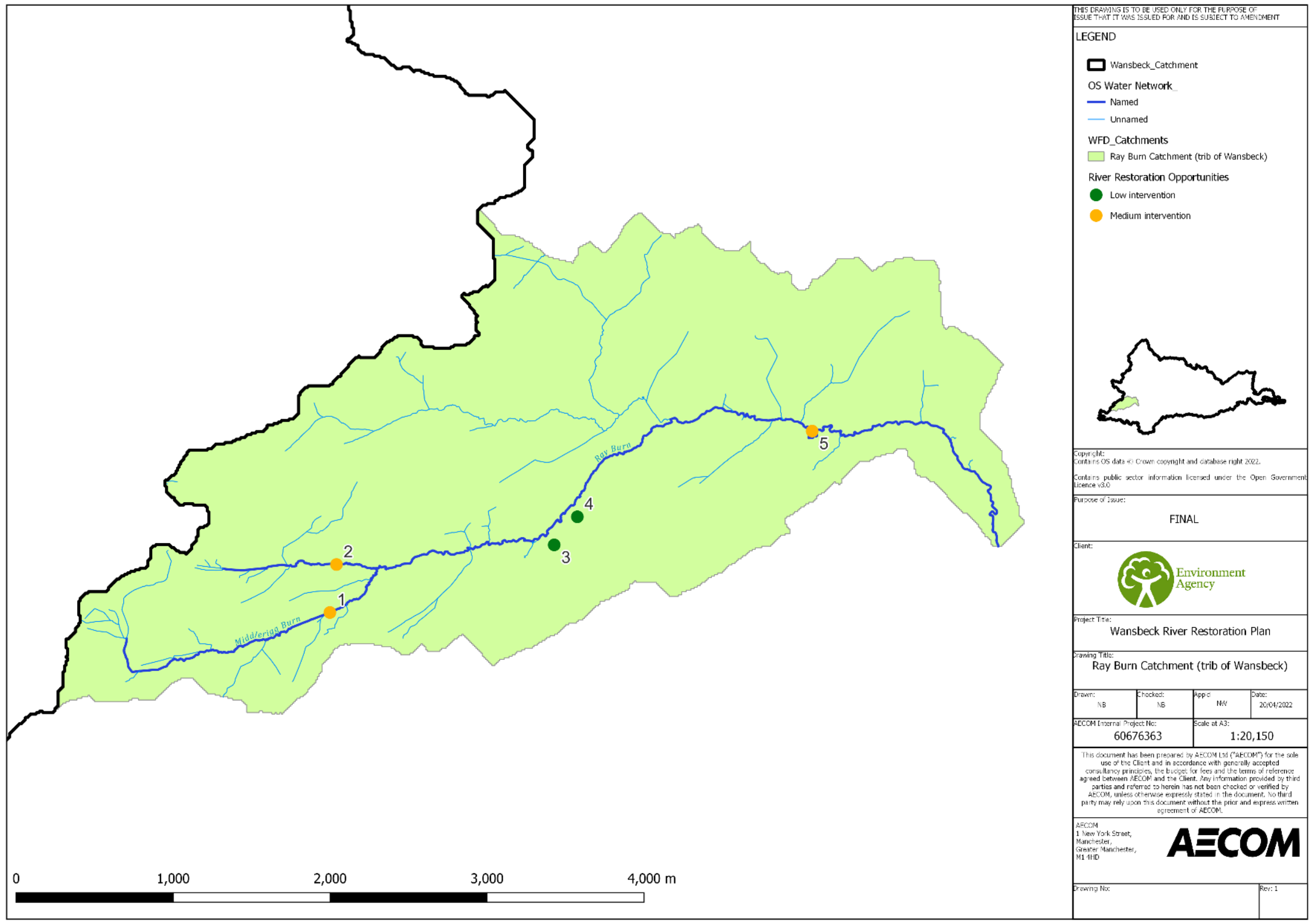
Current WFD Status: Poor

WFD Status Objective: Good by 2021

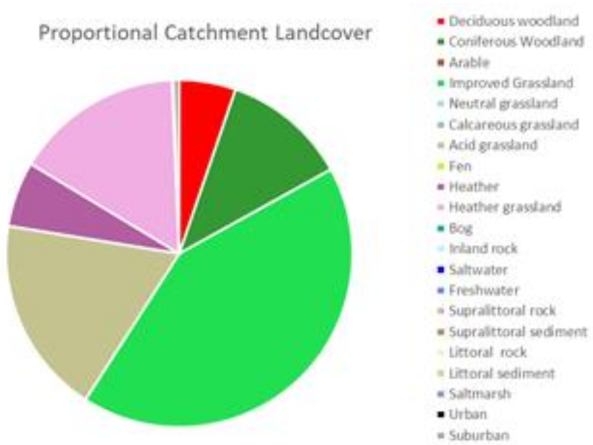
not designated as A/HMWB

RNGA:
- **Pollution from rural areas (Agriculture and rural land management)**

Ray Burn Catchment (trib of Wansbeck)



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Middlerigg Burn	Establish riparian buffer strips, Introduce Woody Habitat, Block ditches and drains (grips)	Medium intervention
2	Ray Burn	Establish riparian buffer strips, Introduce Woody Habitat, Block ditches and drains (grips)	Medium intervention
3	Ray Burn	Eliminate fine sediment sources	Low intervention
4	Ray Burn	Eliminate fine sediment sources	Low intervention
5	Ray Burn	Reconnect Floodplain, Allow development of swamp and pond habitat	Medium intervention



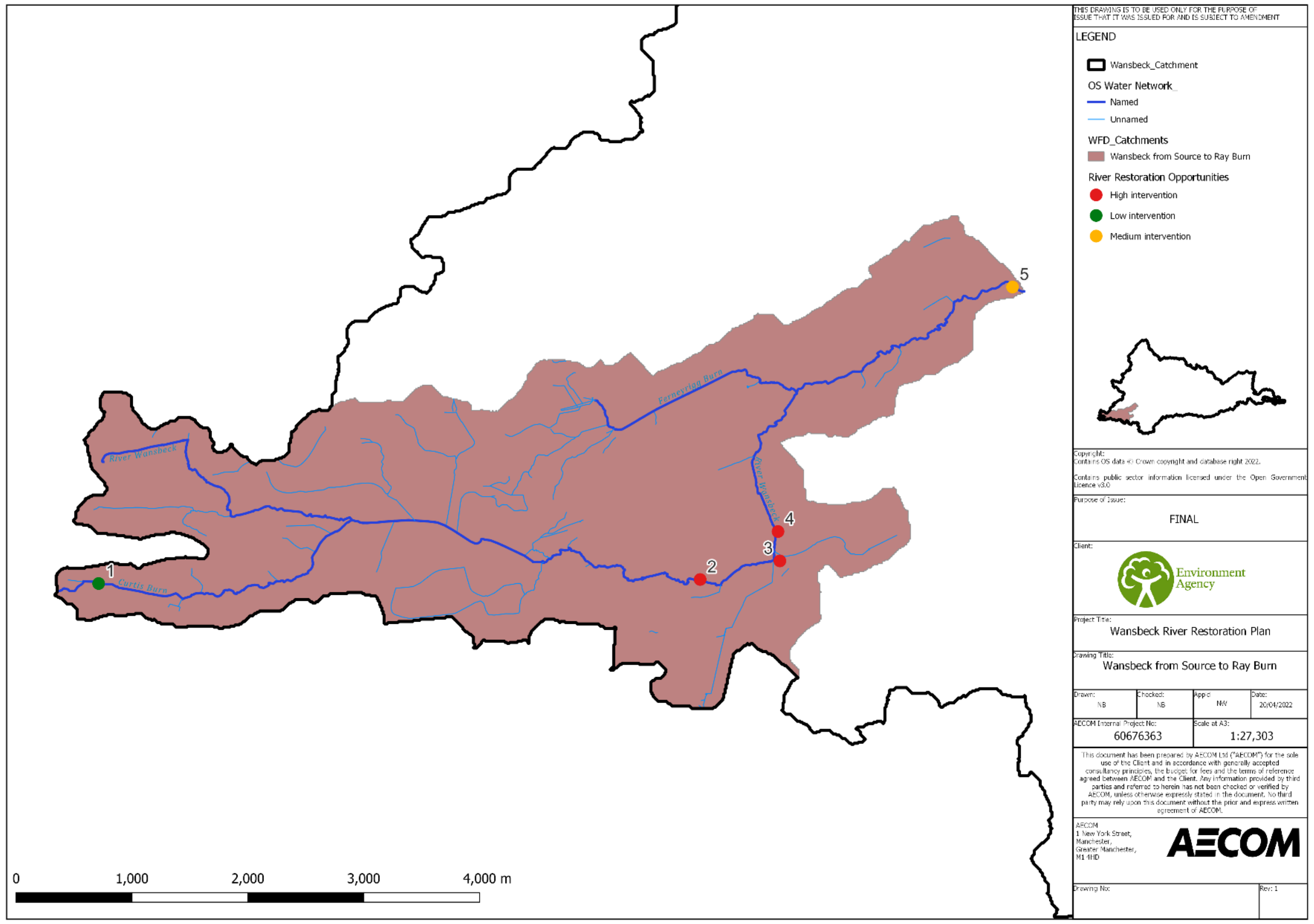
Current WFD Status: Poor

WFD Status Objective: Good by 2027

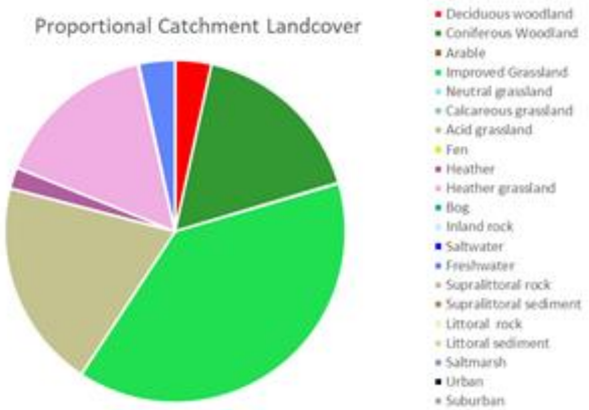
not designated as A/HMWB

RNGA:
- **Pollution from rural areas (Agriculture and rural land management)**

Wansbeck from Source to Ray Burn



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Curtis Burn	Block ditches and drains (grips), Establish riparian buffer strips	Low intervention
2	River Wansbeck	Enhance Sinuosity, Restore to former course, Re-meander, Introduce Woody Habitat, Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips, Strategic fencing, Allow development of wet woodland	High intervention
3	River Wansbeck	Enhance Sinuosity, Restore to former course, Re-meander, Introduce Woody Habitat, Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips, Strategic fencing, Allow development of wet woodland	High intervention
4	River Wansbeck	Enhance Sinuosity, Restore to former course, Re-meander, Introduce Woody Habitat, Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips, Strategic fencing, Allow development of wet woodland	High intervention
5	River Wansbeck	Reconnect Floodplain, Allow development of swamp and pond habitat	Medium intervention



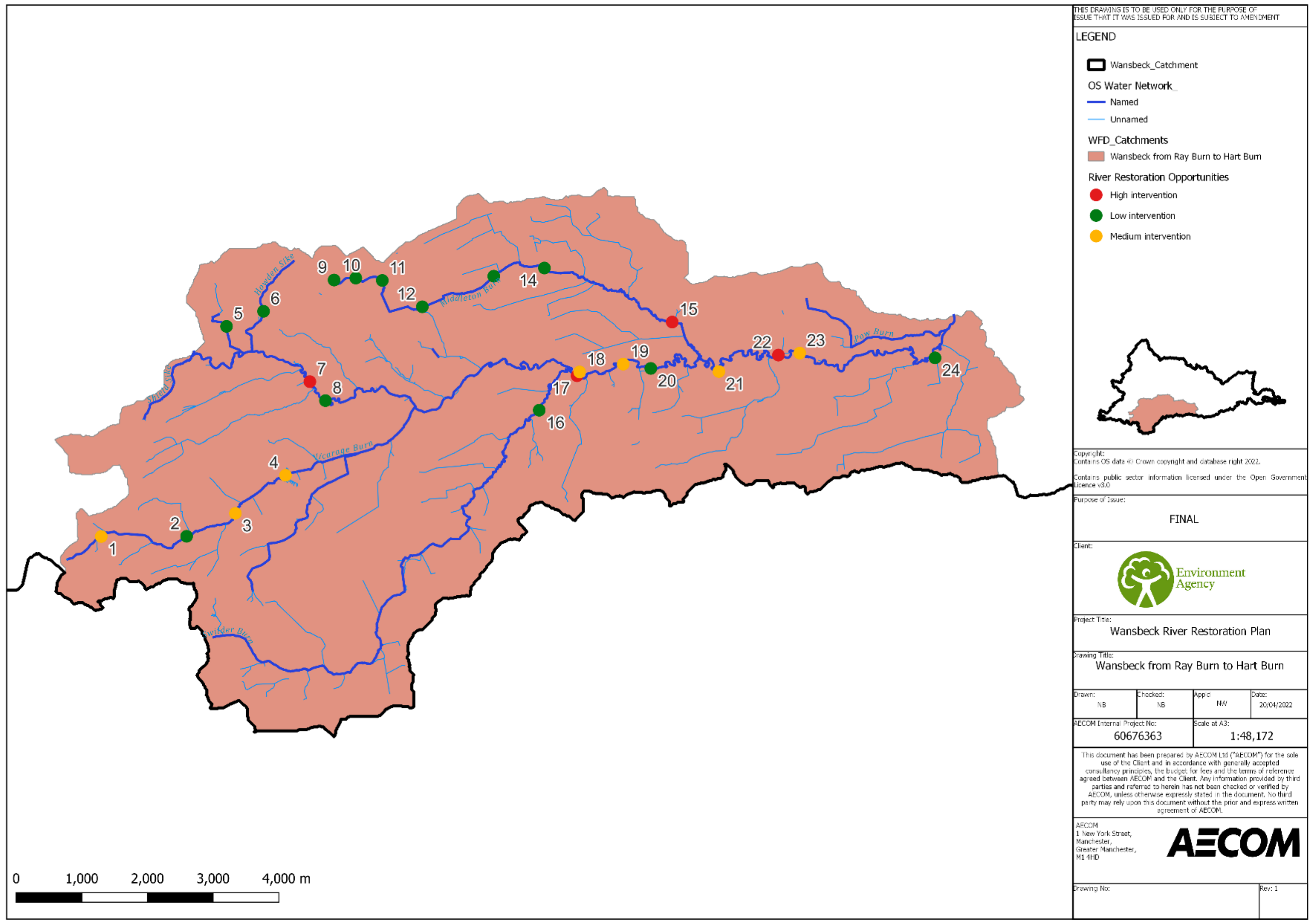
Current WFD Status: Good

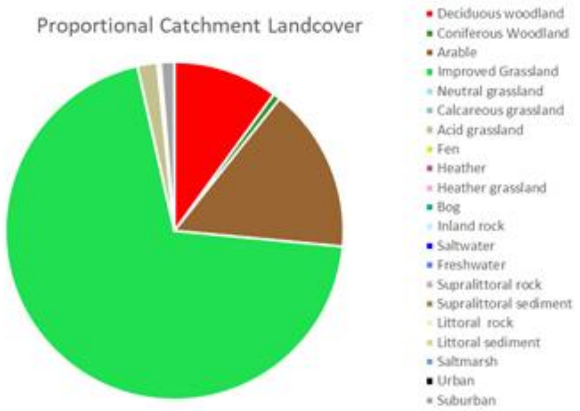
WFD Status Objective: Good by 2015

not designated as A/HMWB

RNGA:
- Not Applicable

Wansbeck from Ray Burn to Hart Burn





Current WFD Status: Poor

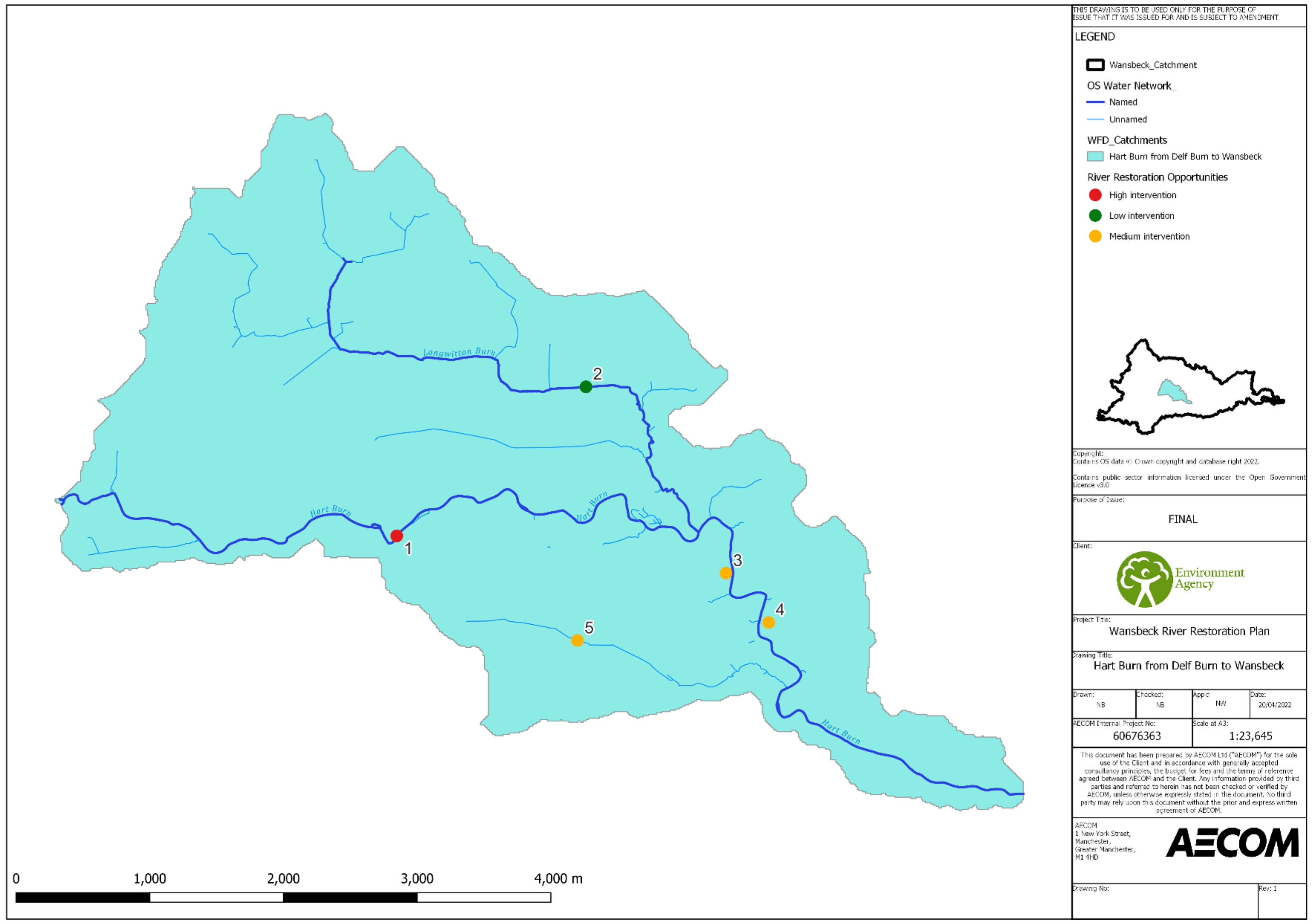
WFD Status Objective: Good by 2027

Heavily Modified

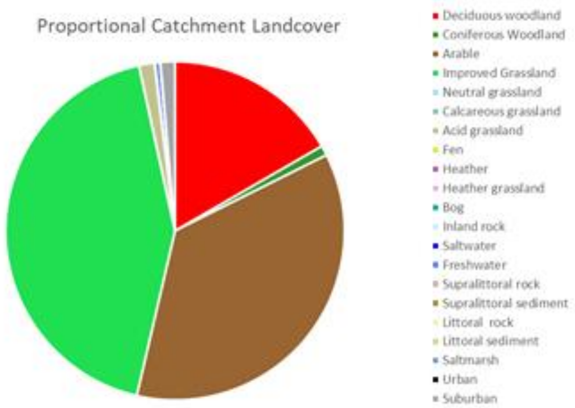
RNGA:
- **Pollution from rural areas (Agriculture and rural land management)**

Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Vicarage Burn	Block ditches and drains (grips), Reconnect Floodplain, Allow development of swamp and pond habitat, Introduce Woody Habitat	Medium intervention
2	Vicarage Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
3	Vicarage Burn	Reconnect Floodplain, Allow development of swamp and pond habitat	Medium intervention
4	Vicarage Burn	Block ditches and drains (grips), Reconnect Floodplain, Allow development of swamp and pond habitat, Introduce Woody Habitat	Medium intervention
5	Whitridge Sike	Establish riparian buffer strips, Manage livestock access to stream, Strategic fencing	Low intervention
6	Howden Sike	Establish riparian buffer strips, Strategic fencing	Low intervention
7	River Wansbeck	Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Establish riparian buffer strips	High intervention
8	River Wansbeck	Establish riparian buffer strips, Strategic fencing	Low intervention
9	Middleton Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
10	Middleton Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
11	Middleton Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
12	Middleton Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
13	Middleton Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
14	Middleton Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
15	Middleton Burn	Enhance Sinuosity, Re-meander, Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Restore to former course, Establish riparian buffer strips	High intervention
16	Swilder Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
17	River Wansbeck	Enhance Sinuosity, Re-meander, Vary bed topology, Reconnect Floodplain, Create floodplain wetland, Restore to former course, Establish riparian buffer strips	High intervention
18	River Wansbeck	Reconnect Floodplain, Allow development of swamp and pond habitat	Medium intervention
19	River Wansbeck	Green erosion protection/prevention, Eliminate fine sediment sources, Manage livestock access to stream, Establish riparian buffer strips, Strategic fencing	Medium intervention
20	River Wansbeck	Allow development of swamp and pond habitat	Low intervention
21	River Wansbeck	Strategic fencing, Establish riparian buffer strips, Green erosion protection/prevention	Medium intervention
22	River Wansbeck	Remove Structure, Strategic fencing, Establish riparian buffer strips	High intervention
23	River Wansbeck	Green erosion protection/prevention, Eliminate fine sediment sources, Manage livestock access to stream, Establish riparian buffer strips, Strategic fencing	Medium intervention
24	River Wansbeck	Allow development of wet woodland, Allow development of swamp and pond habitat	Low intervention

Hart Burn from Delf Burn to Wansbeck



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Hart Burn	Barrier Removal	High Intervention
2	Longwitton Burn	Strategic fencing, Establish riparian buffer strips	Low intervention
3	Hart Burn	Reconnect Floodplain, Create floodplain wetland	Medium intervention
4	Hart Burn	Reconnect Floodplain, Create floodplain wetland	Medium intervention
5	Hart Burn (tributary)	Introduce Woody Habitat, allow development of swamp and pond habitat	Medium intervention



Current WFD Status: Moderate

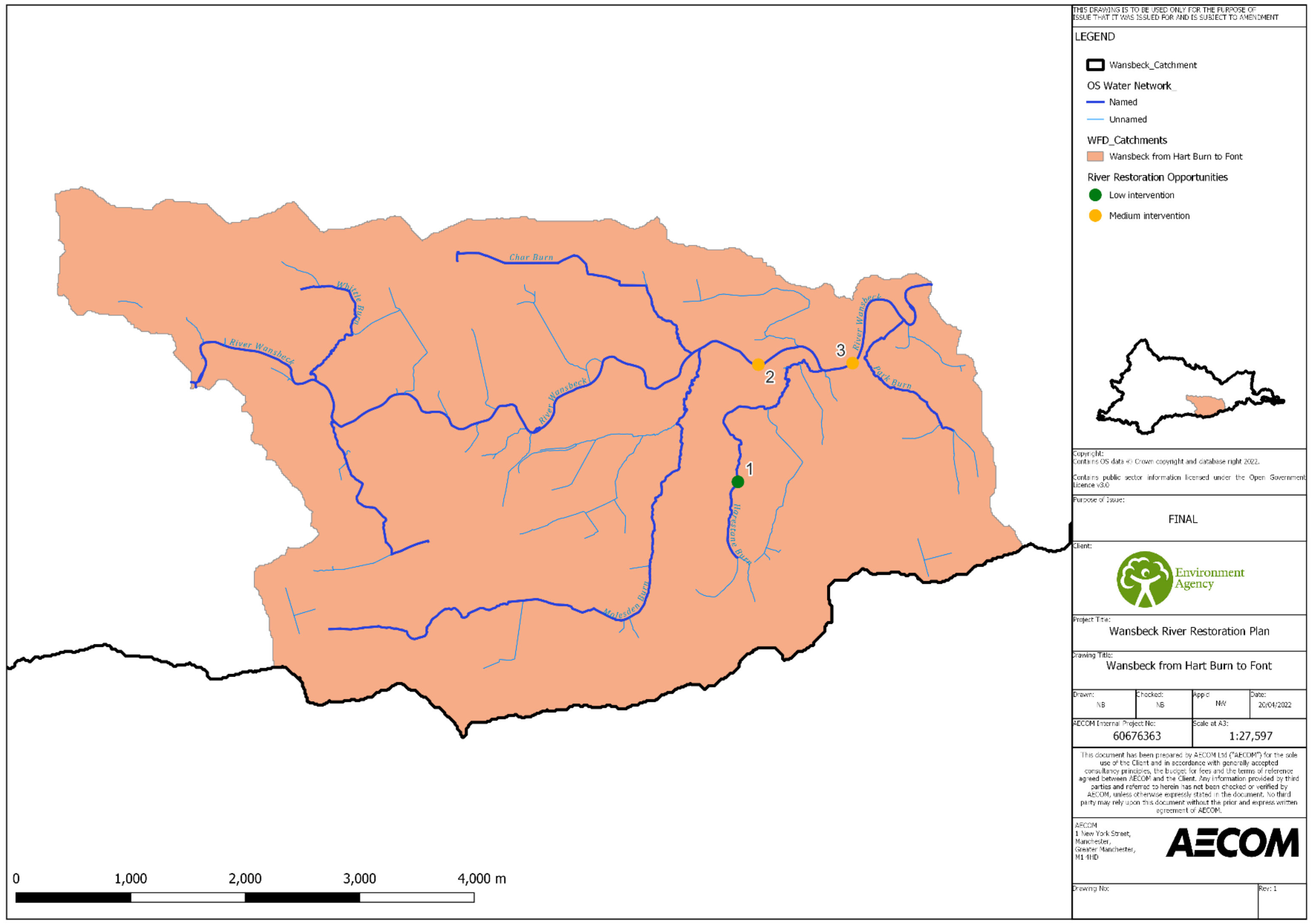
WFD Status Objective: Good by 2027

not designated as A/HMWB

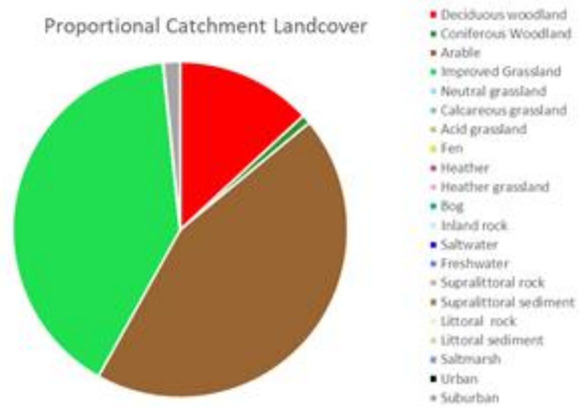
RNGA:

- **Pollution from rural areas (Agriculture and rural land management)**

Wansbeck from Hart Burn to Font



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Harestane Burn	Establish riparian buffer strips	Low intervention
2	River Wansbeck	Create floodplain wetland, Reconnect Floodplain, Raise channel bed	Medium intervention
3	River Wansbeck	Create floodplain wetland, Reconnect Floodplain, Raise channel bed	Medium intervention



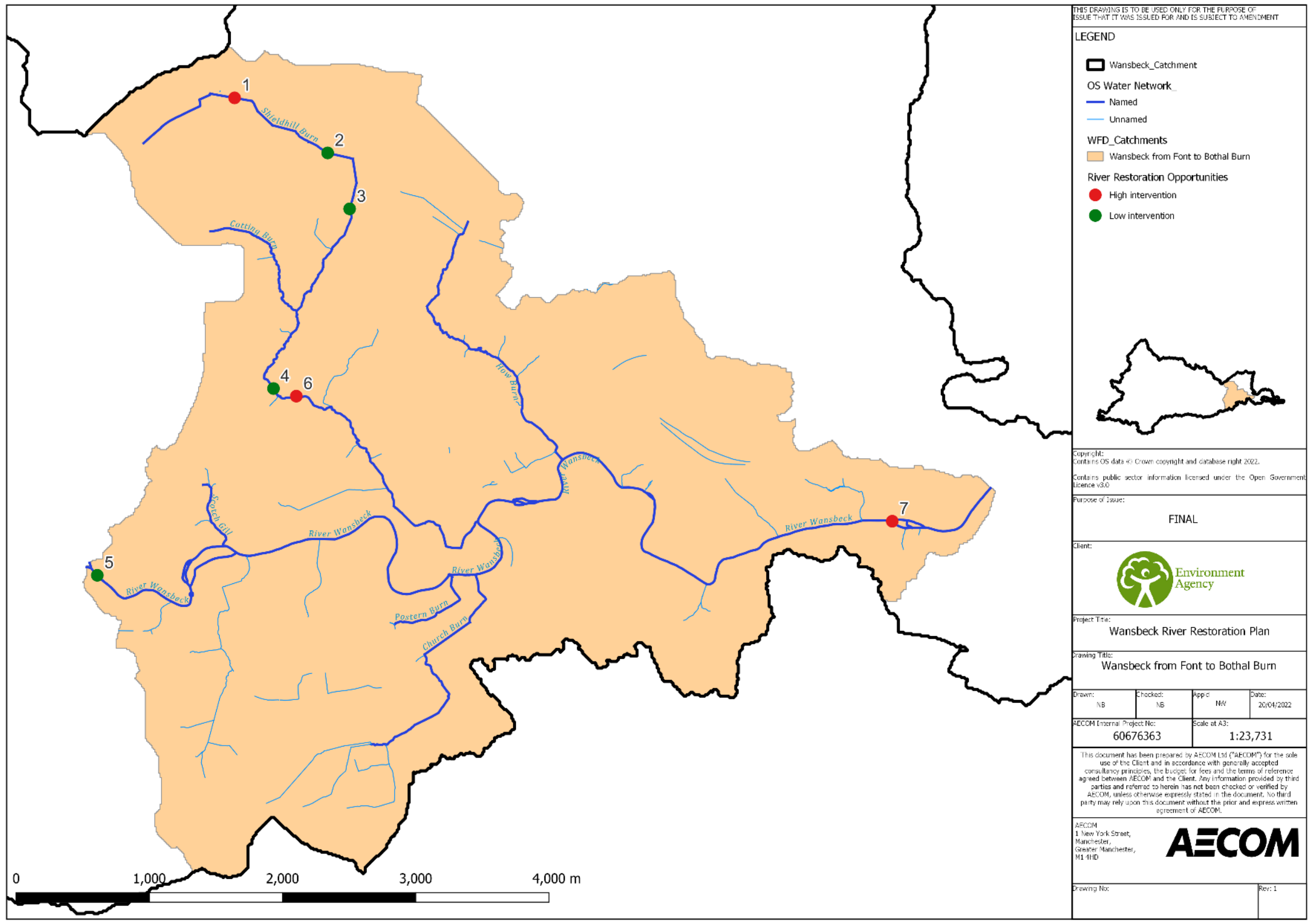
Current WFD Status: Good

WFD Status Objective: Good by 2027

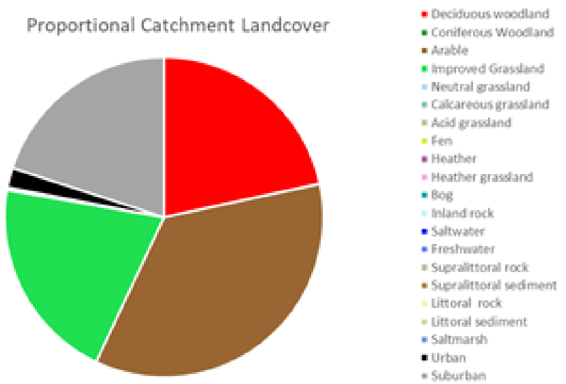
not designated as A/HMWB

RNGA:
- Not Applicable

Wansbeck from Font to Bothal Burn



Site ID	Reach Name	Restoration Opportunities	Level of Intervention
1	Shieldhill Burn	Strategic fencing, Remove Structure, Establish riparian buffer strips, Daylightng	High intervention
2	Shieldhill Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
3	Shieldhill Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
4	Cotting Burn	Establish riparian buffer strips, Strategic fencing	Low intervention
5	River Wansbeck	Establish riparian buffer strips, Strategic fencing	Low intervention
6	Cotting Burn	Remove structure	High intervention
7	River Wansbeck	Remove structure	High intervention



Current WFD Status: Moderate

RNGA:
- **None provided**

WFD Status Objective: Good by 2027

not designated as A/HMWB

Summary

5.2 There are numerous river restoration opportunities across the Wansbeck catchment in varying degrees of scale and extent. Most of these opportunities are concurrent with impacts derived from agriculture, with depleted riparian buffer zones coupled with excessive ingress of agricultural diffuse pollution being an especially prevalent impact found across the catchment. This has been identified by previous studies carried out by the Northumberland Rivers Trust as perhaps the most extensive opportunity but requires widescale implementation in order to contribute to WFD objectives.

5.3 However, a number of watercourses have been extensively physically modified, straightened and realigned primarily to facilitate agriculture and land drainage. This has served to deplete in-channel diversity, curtail natural processes, and disconnect channels from their floodplains, thereby diminishing in-channel, riparian and floodplain habitat, exacerbating downstream flood risk, and contributing to the overall decline in catchment biodiversity.

5.4 To that end, the desk-based search for appropriate opportunities has revealed a number of sites where extensive and ambitious restoration measures could take place. These are situated in reaches that have not received prior enhancement, are owned by landowners whom are keen to enhancement biodiversity on their property, and that are physically conducive to river/floodplain restoration.

Multi Criteria Analysis

5.5 MCA has been performed in order to rationalise the longlist of opportunities and reveal a refined shortlist of appropriate river restoration sites. Watercourses that present more than one opportunity have been combined. The MCA addresses the following questions:

- Does the option potentially provide a potential benefit or disbenefit regarding hydromorphology and naturalisation?
- Does the scheme potentially provide a potential benefit or disbenefit regarding riverine habitat?
- Does the option potentially provide a potential benefit or disbenefit regarding fish passage?
- Does the option potentially provide a potential benefit or disbenefit regarding water quality?
- Does the option potentially provide a potential benefit or disbenefit regarding flood risk?
- Does the option potentially provide a potential benefit or disbenefit from a physical landscape or visual perspective?
- Does the option potentially provide a potential benefit or disbenefit regarding recreation and amenity?
- Does the option potentially provide a potential benefit or disbenefit regarding heritage?
- Does the option potentially provide a potential benefit or disbenefit regarding contaminated land and sediment?
- Does the option potentially provide a potential benefit or disbenefit regarding sustainability/ ongoing maintenance?
- Is the option assumed to be on government land or privately owned land?
- Is the option considered to be of low, medium or high cost?

Summary

5.6 The six shortlisted sites meet the majority of criteria set out in the MCA insofar as they offer considerable potential benefits to riverine habitat, restoration of natural geomorphological processes, flood risk and amenity value etc. The majority, however, are of moderate cost, but the level of benefit is expected to be good value in terms of the benefits they would deliver.

Table 5-2 River Restoration Options Longlist

WFD Waterbody	Named River	Does the option provide a potential benefit or disbenefit regarding hydromorphology and naturalisation?	Does the scheme provide a potential benefit or disbenefit regarding habitat?	Does the option provide a potential benefit or disbenefit regarding fish passage?	Does the option provide a potential benefit or disbenefit regarding water quality?	Does the option provide a potential benefit or disbenefit regarding flood risk?	Does the option provide a potential benefit or disbenefit from a physical landscape or visual perspective?	Does the option provide a potential benefit or disbenefit regarding recreation and amenity?	Does the option provide a potential benefit or disbenefit regarding heritage?	Does the option provide a potential benefit or disbenefit regarding contaminated land and sediment?	Does the option provide a potential benefit or disbenefit regarding sustainability/ ongoing maintenance?	Is the option assumed to be on government land or privately owned land?	Is the option considered to be of low, medium or high cost?	TOTAL	Rank
Wansbeck from Ray Burn to Hart Burn	River Wansbeck	2	2	2	2	2	2	1	0	2	2	P	Medium	17	1
Wansbeck from Source to Ray Burn	River Wansbeck	2	2	1	2	2	2	1	1	2	2	P	Medium	17	1
Wansbeck from Ray Burn to Hart Burn	Middleton Burn	2	2	1	2	2	2	1	0	2	2	P	Medium	16	3
Hart Burn from Delf Burn to Wansbeck	Hart Burn	2	2	1	2	2	2	1	0	2	1	P	Low	15	4
Font from Source to Wansbeck	Fence Burn	2	2	2	1	1	2	0	0	2	2	P	Medium	14	5
Ray Burn Catchment (trib of Wansbeck)	Ray Burn	2	2	0	2	2	2	0	0	2	2	P	Medium	14	5
Delf Burn Catchment (trib of Hart Burn)	Donkinrigg Burn	2	2	0	1	2	2	0	0	2	2	P	Medium	13	7
Font from Source to Wansbeck	Cowclose Burn	1	1	2	2	1	2	0	0	2	2	P	Medium	13	7
Font from Source to Wansbeck	River Font	1	2	2	1	1	2	0	0	2	2	P	Medium	13	7
Hart Burn from Source to Delf Burn	Hart Burn	1	2	0	2	2	2	0	0	2	2	P	Medium	13	7
Font from Source to Wansbeck	Cleugh Burn	1	1	0	2	2	2	0	0	2	2	P	Medium	12	11
Font from Source to Wansbeck	Benridge Burn	1	1	0	2	1	2	0	0	2	2	P	Low	11	12
Font from Source to Wansbeck	Harry's Burn	1	1	2	1	0	2	0	0	2	2	P	Low	11	12
Hart Burn from Source to Delf Burn	Ottercops Burn	1	2	0	1	1	2	0	0	2	2	P	Low	11	12
Delf Burn Catchment (trib of Hart Burn)	Harwood Burn	1	1	0	1	1	2	0	0	2	2	P	Low	10	15
Font from Source to Wansbeck	Fallowlees Burn	1	1	0	2	0	2	0	0	2	2	P	Low	10	15
Hart Burn from Source to Delf Burn	Birky Burn	1	2	0	2	1	2	0	0	1	1	P	Low	10	15
Wansbeck from Ray Burn to Hart Burn	Vicarage Burn	1	2	0	1	1	2	0	0	1	2	P	Low	10	15
Bothal Burn Catchment (trib of Wansbeck)	Bothal Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Bothal Burn Catchment (trib of Wansbeck)	Brocks Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Bothal Burn Catchment (trib of Wansbeck)	Longhirst Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Font from Source to Wansbeck	Blagdon Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Font from Source to Wansbeck	Chartner Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Font from Source to Wansbeck	Cold Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Font from Source to Wansbeck	Mere Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19

WFD Waterbody	Named River	Does the option provide a potential benefit or disbenefit regarding hydromorphology and naturalisation?	Does the scheme provide a potential benefit or disbenefit regarding habitat?	Does the option provide a potential benefit or disbenefit regarding fish passage?	Does the option provide a potential benefit or disbenefit regarding water quality?	Does the option provide a potential benefit or disbenefit regarding flood risk?	Does the option provide a potential benefit or disbenefit from a physical landscape or visual perspective?	Does the option provide a potential benefit or disbenefit regarding recreation and amenity?	Does the option provide a potential benefit or disbenefit regarding heritage?	Does the option provide a potential benefit or disbenefit regarding contaminated land and sediment?	Does the option provide a potential benefit or disbenefit regarding sustainability/ ongoing maintenance?	Is the option assumed to be on government land or privately owned land?	Is the option considered to be of low, medium or high cost?	TOTAL	Rank
Font from Source to Wansbeck	Newbiggin Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Font from Source to Wansbeck	Smiddy Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Hart Burn from Delf Burn to Wansbeck	Longwitton Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Wansbeck from Font to Bothal Burn	Cotting Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Wansbeck from Font to Bothal Burn	River Wansbeck	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Wansbeck from Font to Bothal Burn	Shieldhill Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Wansbeck from Hart Burn to Font	Harestane Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Wansbeck from Hart Burn to Font	River Wansbeck	1	1	0	1	2	2	0	0	0	2	P	Medium	9	19
Wansbeck from Ray Burn to Hart Burn	Swilder Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Wansbeck from Ray Burn to Hart Burn	Whitridge Sike	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Wansbeck from Source to Ray Burn	Curtis Burn	1	1	0	1	0	2	0	0	2	2	P	Low	9	19
Font from Source to Wansbeck	Trewitley Burn	1	1	2	1	0	1	0	0	1	0	P	Low	7	37
Hart Burn from Source to Delf Burn	Cowford Sike	1	1	0	1	1	1	0	0	1	1	P	Low	7	37
Ray Burn Catchment (trib of Wansbeck)	Middlerigg Burn	0	1	0	1	1	1	0	0	1	2	P	Low	7	37
Wansbeck from Ray Burn to Hart Burn	Howden Sike	1	1	0	1	0	1	0	0	2	1	P	Low	7	37

6. Stakeholder Engagement

6.1 Two stakeholder meetings were held during the project. The first, held on March 2nd 2022, was intended to discuss technical aspects of the project with the Local Rivers Trust, the National Trust and Groundwork, the EA and Natural England, all of whom have had significant involvement in improving biodiversity across the catchment. The purpose of the meeting was to gain an understanding of existing and historical projects in the catchment.

6.2 The second stakeholder meeting, held on 3rd March 2022, was intended to discuss the practical aspects of the project in terms of implementation and landowner buy-in.

Technical Stakeholder Group

Attendees

1. Kirstin Aldous, ecologist AECOM
2. Neil Burrows, geomorphologist, AECOM
3. Neil Williams, geomorphologist, AECOM
4. Stephanie Peay, ecologist, AECOM
5. Lydia Nixon, LNRS lead, Natural England
6. Bob Cussen, Tree Action Plan, Natural England
7. Paul Hewitt, Estate Manager, Wallington Estate, National Trust
8. Michelle MacCallam, landscape architect. Groundwork NorthEast
9. Peter Kerr, Director, Northumbria Rivers Trust,
10. Abi Mansley, GIS analyst and LNRS, Northumberland County Council
11. Heather Harrison, Environment Agency project manager
12. David Feige, environmental design team manager and county ecologist, Northumberland County Council
13. Mark Childs, project manager Great Northumberland Forest

Summary

6.3 It was highlighted that there had already been work undertaken within the catchment and further consultation with the Rivers Trust was required to share information.

6.4 Fencing / grazing has been identified as is a key issue affecting water quality throughout the catchment.

6.5 Maps show lots of watercourses as straight lines, there is scope to change this in some cases.

6.6 Woody debris dams/leaky dams need to be correctly positioned to avoid exacerbating problems. Any changes proposed also need to consider fish passage. Fallen trees following Storm Arwen could be a potential source of material for well-placed dams.

Farmer and Landowner Group

Attendees

1. Neil Burrows, geomorphologist, AECOM
2. Kirstin Aldous, ecologist AECOM
3. Lydia Nixon, LNRS lead, Natural England
4. Heather Harrison, Environment Agency project manager
5. Charlie Bennett, landowner Middleton North Estate
6. John Anderson, Kirkharle
7. James Cookeson, Meldon Park
8. George Dodds, George Dodds and Co
9. Harry Baker Creswell, Preston Mains Farm

Summary

6.7 The farmer and landowner group generally reacted positively to the project and welcomed opportunities to deliver nature-based solutions within the catchment.

6.8 Where reviewing the primary habitat maps, landowners felt there was still too much 'white space', and the maps did not capture all of the habitat creation and enhancement work that was already being completed. It was discussed that some landowners (such as the National Trust) have more resources available to them to map their land (i.e. volunteers) and the abundance of data around the Wallington Estate may not indicate that the habitats were in better condition. Many farmers have already made management plans for their land which seek to identify the best areas to make improvements for wildlife.

6.9 Farmers and landowners indicated that they would like a greater understanding of how biodiversity improvements might be funded. Farmers who were already making such improvements on their farms should not miss out. Whilst the strategic approach to the project was understood, landowners wanted to have a say in how the land might be managed in the future and preferred a 'bottom up' rather than 'top-down' approach.

6.10 Farmers felt that mapping the quality of the habitats present was a useful exercise, and that 'knowledge is power'. It was noted that Information on land condition is already collected as part of agri-environment scheme applications, but this is not publicly available.

6.11 The abundance of ridge and furrow fields within the catchment was discussed – these have historic value and the topographical variation provides a microclimate of wet and dry areas that can be botanically more diverse. There are more areas of wet, marshy grassland within the catchment than are showing on the maps.

6.12 Habitats such as woodland require a commitment over a long period of time. There is a focus on the environment currently, but this could switch to food production depending upon politics / world events. There was frustration with current schemes – there were many comments suggesting that these were administration heavy, and farmers often don't get paid on time.

6.13 It was suggested that where farmers have made improvements to their land, they could hold workshops or training sessions to demonstrate what is possible to others.

7. Detailed Restoration Plans

7.1 The following section outlines the shortlisted river restoration sites identified through the multi-criteria analysis above. Six restoration sites are presented, each of which delivers a broad range of opportunities that would contribute to improving biodiversity and natural form and function, in addition to creating habitat linkages with restorable terrestrial habitats revealed through AECOM's Habitat Restoration and Creation Plan.

7.2 The six restoration sites, shown in Figure 7-1, are focussed within the south west corner of the catchment. There are several reasons for this: the first is that this region has numerous large-scale river restoration opportunities that are not constrained by any of the previously criteria – existing broadleaved woodland, local urban areas/infrastructure etc. In addition, a considerable proportion of this area of the catchment is owned by landowners who are keen to Implement measures to improve biodiversity. Finally, this region has been identified as a priority by the Northumberland Rivers Trust in their 'Wilds of Wanney' study. Thus, the restoration options presented below would contribute significantly to the WFD status of the host water bodies.

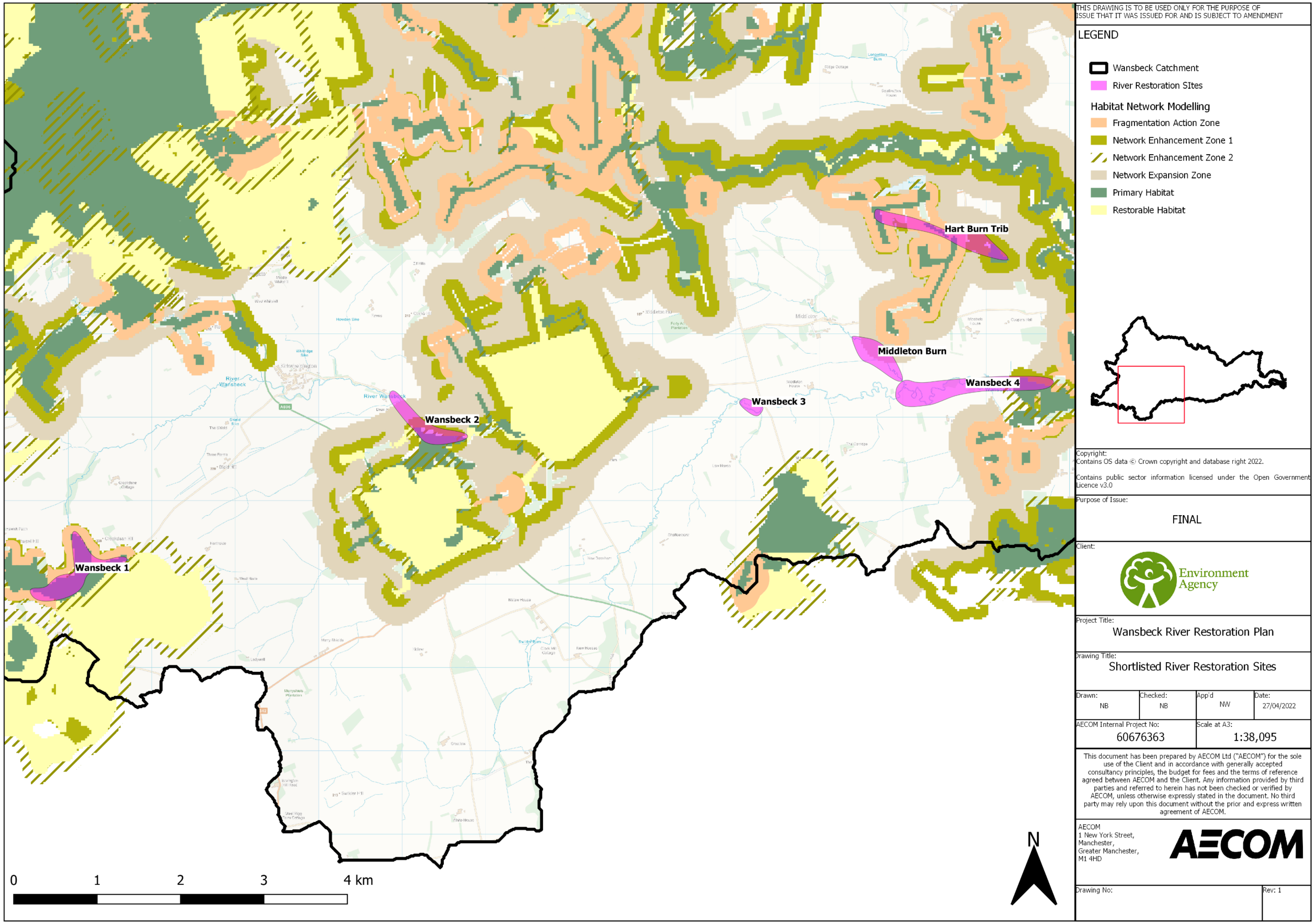


Figure 7-1 shortlisted river restoration sites and their spatial relationship with identified habitat networks.

River Wansbeck (Site 1)

Baseline Characteristics

Channel form

7.3 The reach begins at the downstream extent of a laterally confined valley, whereupon topography opens into a flat, expansive and unconstrained alluvial plain. However, the channel has, at some point in history (pre-Ordnance Survey), been realigned to the boundary of its floodplain, presumably to develop farmland. As a result, the channel resides within a somewhat over-deepened corridor that is likely disconnected from its floodplain. However, despite its modified character, the channel exhibits some degree of morphological recovery, with well-defined pool-riffle sequencing, gravel forms and active localised erosion that gives rise to a moderately sinuous planform, observable throughout the reach.

Substrate Conditions

7.4 Channel substrate is comprised of a range of particle clast sizes ranging from silt and sand up to coarse gravel and cobbles. A well-defined layer of alluvial deposits, readily observable in the exposed banks of the channel, provides an abundant source of coarse material. However, localised bank poaching by livestock results in ingress of fines; though, generally, the largely gravel substrate was noted to be clean with minimal impact from localised sources of fines.

7.5 Gravel forms were noted throughout the reach, including small riffles and bar features. Larger cobble/small boulder particles were covered in a layer of moss and other vegetation suggesting that they have remained static for some period of time, perhaps as a consequence of a regulated flow regime exerted by Sweethope Loughs, located approximately 1.5km upstream, which are artificial, dammed lakes and thus likely reduce peak flows and the conditions required to intermittently transport larger calibre sediments.

Flow Conditions

7.6 Flow conditions on the day of survey were at, or close to, baseflow following several days of dry weather. The channel exhibited some hydraulic variability generated by the aforementioned pool-riffle sequences, scour holes, sediment berms and assemblages of macrophytes, but this is limited by its modified, entrenched character that serves to curtail natural processes and confines flow to a narrow, over-deep channel.

Floodplain Characteristics

7.7 The floodplain appears to be significantly disconnected from its channel as a result of anthropogenic modification. A complex arrangement of relict palaeo-channel features is clearly observable in aerial photographs; however, these are inactive and are unlikely to become inundated, even during extreme storm events. Whilst the floodplain at this location is not heavily pressured in terms of livestock access and grazing, high-quality floodplain habitat is generally absent and is instead occupied largely by terrestrial grasses. Very little wetland features were noted, other than a few localised patches that sit within the former river channel system. Broadly, though, the floodplain is poorly hydrologically connected both laterally to its channel, and vertically to the underlying water table which is probably artificially low due to land management and drainage.

Riparian Zone

7.8 The channel's riparian zone is poor quality, with little to no vegetation complexity occupying its adjacent corridor. Though grazing pressure is low, livestock appears to have occasional access to the channel which probably prevents vegetation to flourish in addition to contributing to bank poaching.

Modifications

7.9 Though the reach is completely modified, there are no in-channel structures or bank revetments that curtail natural processes. There are, however, a number of locations that are used as informal ford crossings, but these have only a localised and minor impact. As previously discussed, the flow regime of the reach is probably modified by Sweethope Loughs leading to reduced peak flows, though no specific data on this are available at the time of writing.

Restoration Opportunities

7.10 There are an abundance of river restoration opportunities through this reach, owing to the degree to which the channel has been impacted throughout human history and the extent of its currently degraded floodplain. The predominant restoration opportunity consists of diverting the present-day channel, the result of anthropogenic modification, to its former natural course by re-connecting the clearly distinguishable palaeo-channels that meander across the adjacent floodplain. This would generate a significantly greater length of channel, introduce sinuosity, and reconnect the channel with its floodplain at more frequently and extensively than current regime. Palaeo-channel reconnection could potentially be achieved at relatively low cost for high gain, by strategic breaching of the current channel banks adjacent to the straightened reaches. Strategic flow reconnection would enable the river to do the geomorphological work to restore itself.

7.11 A variety of features could be incorporated into the diverted channel, including bedforms (riffles and bar features) to promote hydraulic complexity and a mosaic of in-channel biotopes; lowered and inset berms to provide semi-wetland features and growing media for marginal plant species; and coarse wood habitat to generate geomorphic complexity and habitat. Ideally these would be allowed to evolve as a result of reconnected flow processes, without the cost of designing and building naturalisation features with ‘heavy’ interventions.

7.12 However, restoration opportunities extend far beyond creating in-channel habitat alone. By diverting the channel, there is significant potential for full-valley restoration. As previously described, increasing channel length would re-connect the floodplain both during intermittent out-of-bank flood events, and more lastingly as a result of a higher water table and restored local hyporheic flow. This would allow both for the creation of a high-quality riparian zone immediately adjacent to the channel, and a rich and varied mosaic of habitat across the wider floodplain. Accordingly, wetland areas could be installed in addition to informal scrape features, each of which would provide niche bog habitat. The existing channel could be left as an open, linear ponded feature to maintain its habitat value. The wider floodplain would potential self-recover; but there is excellent potential for floodplain wet woodland creation.

7.13 There are clear benefits of restoring this reach for biodiversity and habitat enhancement including linkages with the terrestrial environment and associated increased species diversity of birds, invertebrates, mammals and fish. However, there is considerable potential for this site to deliver on other elements; including a positive contribution to flood risk as a result of increased floodplain storage; carbon sequestration benefits due to improved floodplain and wetland habitat creation (which are excellent carbon stores); and considerable amenity value potential. A conceptual plan of restoration opportunities is shown in Figure 7-2 below.

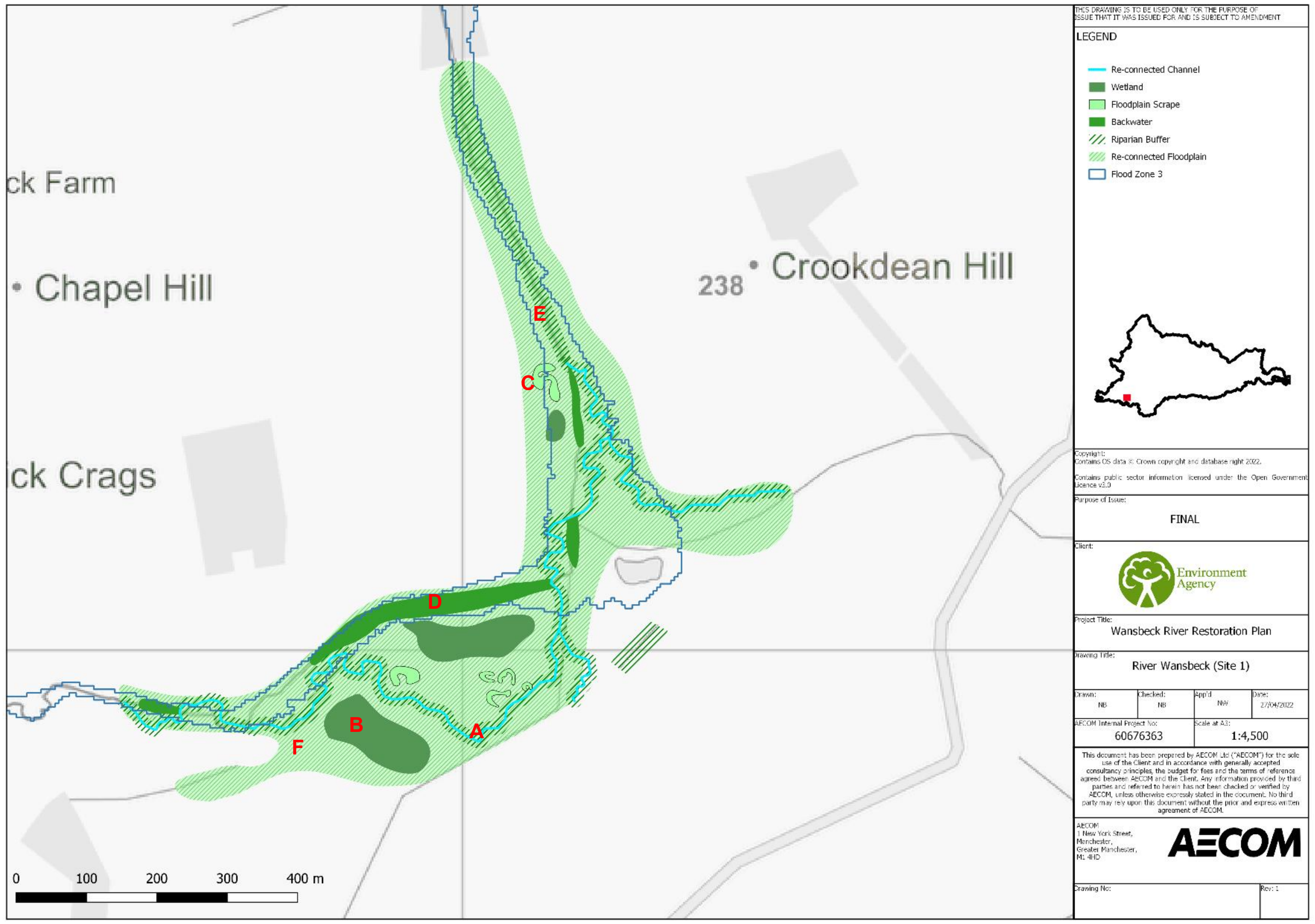


Figure 7-2 Conceptual restoration plan for River Wansbeck (site 1)

Point	Feature	Description
A	Re-connected palaeo-channel	The former natural course of the channel that is visible in the landscape as relic palaeo-channel forms. Reconnecting these would significantly increase channel length, improve lateral connectivity, and thus, promote restoration of the wider floodplain-channel system.
B	Wetland/wet woodland	Diverting the channel and raising the water table would permit installation of groundwater-dependant floodplain wetlands. These features would be planted with an appropriate plant seed/plug mix to create a rich mosaic of wetland features across the floodplain.
C	Floodplain scrape	Floodplain scrapes are informal excavations in the landscape that provide topographic variance and thus additional niche habitat for a range of flora and fauna. They are simple to implement and cost-effective since they can be left to self-seed.
D	Open backwater	Although the existing channel is modified and sits within an over-deep corridor, it still provides some habitat benefit. It would be preferable to leave sections of the existing channel open to provide linear wetland features.
E	Riparian buffer strip	A strip of vegetation would be implanted adjacent to the proposed channel diversion to generate high quality riparian habitat. The feature would comprise a seed mix of appropriate semi-aquatic species.
F	Re-connected floodplain	Indicative re-connected floodplain extent. Improved hydrological connectivity would promote recovery of floodplain and groundwater-dependant habitats.

A. Riffle-pool unit.

B. Over-deep and straight section.

C. localised flow complexity within an over-deep corridor.

D. livestock access point and associated bank poaching.

E. Localised width and depth variation with poor riparian habitat.

F. Localised floodplain bog habitat.

River Wansbeck (Site 2)

Baseline Characteristics

Channel form

7.14 The River Wansbeck at this location exhibits a rich mosaic of in-channel habitat that is promoted and maintained by relatively unimpeded natural geomorphological processes. The channel is laterally unconfined with no extensive revetments to inhibit erosive processes, giving rise to a dynamic, active system that is broadly in a state of morphological equilibrium. The channel is highly sinuous which further promotes hydraulic complexity: deep pools are situated on the outside of meanders while point bars are located on the inside of bends. Active accretion of adjacent point bar features concentrates flow and energy to the opposite banks, which in turn promotes active bank erosion processes that are evident throughout the reach and largely driven by cantilever mass failure and basal washout processes.

7.15 Sequences of riffle features, spaced at approximately five to seven channel widths, are located throughout the reach, in addition to low-lying berms, chute channels and coarse woody habitat, which all contribute to the reach's overall habitat complexity and value.

Substrate Conditions

7.16 Channel substrate composition is similarly complex and comprises a wide range of sediment size classes, from silt and sand, through gravels and cobbles, up to boulders; however, gravel is the dominant substrate material. Bank material is comprised of clayey soils that overlay a layer of well-sorted alluvial deposits that provide an abundant source of coarse gravel to the channel. Active erosion is also likely to periodically introduce fines to the system; but in-channel substrate was noted to be relatively free from excessive ingress of silt and organic material. Larger sediments have a thick layer of moss growing on them, suggesting that they have remained stable for some time – moss is incapable of establishing itself of particles that are frequently entrained and transported.

7.17 The aforementioned riffle features within the reach are slightly armoured which promotes a degree of permanence; while smaller, loose gravels dominate point bar features, suggesting that they are frequently replenished in response to elevated flow events. A considerable quantity of water crowfoot *Ranunculus Sp.* was observed throughout the reach, further suggesting that the channel's substrate is clean and generally free from excessive nutrient loading and ingress of diffuse-source fines.

Flow Conditions

7.18 The interplay of complex hydraulics, sinuous planform and varied bedforms gives rise to a diversity of flow conditions within the reach. There are areas of shallow, turbulent run and riffle flow types, interspersed with deeper pool and glide features. There are no significant structures in the reach that influence flow conditions; however, a concrete ford structure at the upstream end of the reach impounds flow to a small degree, but its influence appears to be localised.

Floodplain Characteristics

7.19 The floodplain of the River Wansbeck in this reach is in less favourable condition that its river channel. It is predominantly comprised of rough pasture and grasses, although grazing pressure appears to be relatively low in comparison to other areas of the catchment, though livestock has free access to the channel during spring a summer. Nevertheless, habitat complexity is relatively low. There are, however, occasional low-lying berm features adjacent to the channel that provide some localised habitat diversity in addition to pockets of bog and wetland on the floodplain. Moreover, strands of recent flood trash on the floodplain suggest that lateral connectivity is reasonably frequent.

Riparian Zone

7.20 The channel's adjacent riparian zone also appears to be of relatively low quality; though it is noted that early Spring is not an ideal time of year to survey plants since growth is minimal – additional survey would be beneficial during an optional survey window. Nevertheless, the riparian zone is likely to be somewhat fragmented, with occasional alder trees providing some localised shade and refuge habitat at the root base. The aforementioned low berm features also provide localised but well-connected riparian habitat; however, their quality is potentially limited by livestock access.

Modifications

7.21 The reach is relatively, but not completely, free from anthropogenic modification. As previously described, a concrete ford crossing structure is located at the upstream extent of the reach which impounds flow and likely impedes sediment transport processes, as well as presenting a barrier to ecological connectivity at lower flows. In addition, there is a heavily revetted bank just downstream of the ford, where a farm tracks run immediately adjacent to the channel for a short distance. Finally, livestock access is likely to adversely modify the composition and quality of riparian and floodplain habitat. At the time of writing (April 2022) proposals for a new quarry near to the reach are being submitted for planning[3]. The proposed quarry site would be directly hydrologically connected to the reach as it lies on a series of small tributaries streams of the River Wansbeck. Quarrying activity may present a significant risk to the water quality of the reach and thus may threaten national important species that are known to occupy the River Wansbeck at this location, most notably white clawed crayfish.

Restoration Opportunities

7.22 The relatively natural condition of the channel and its high sensitivity as white clawed crayfish habitat limits opportunities for in-channel restoration, so it is recommended that disruption is avoided. However, the reach could be improved by implementing simple enhancement measures on the floodplain and riparian zone. Restricting livestock access to the floodplain would permit reinstatement of vegetation and eliminate bank poaching. Excavation of informal floodplain scrapes would generate topographic variation and, therefore, niche habitat that would recover with minimal to no further intervention. Implementation of a high-quality riparian zone consisting of native semi-aquatic plant species and trees would improve lateral ecological connectivity, provide channel shading and a source of woody habitat that would provide light-touch benefits to the channel in the medium to long-term. A conceptual plan of restoration opportunities is shown in Figure 7-3 below.

[3] Northumberland Development Plan Policies Map (arcgis.com) – Northumberland Local Plan Policy MIN9 – Accessed April 2022

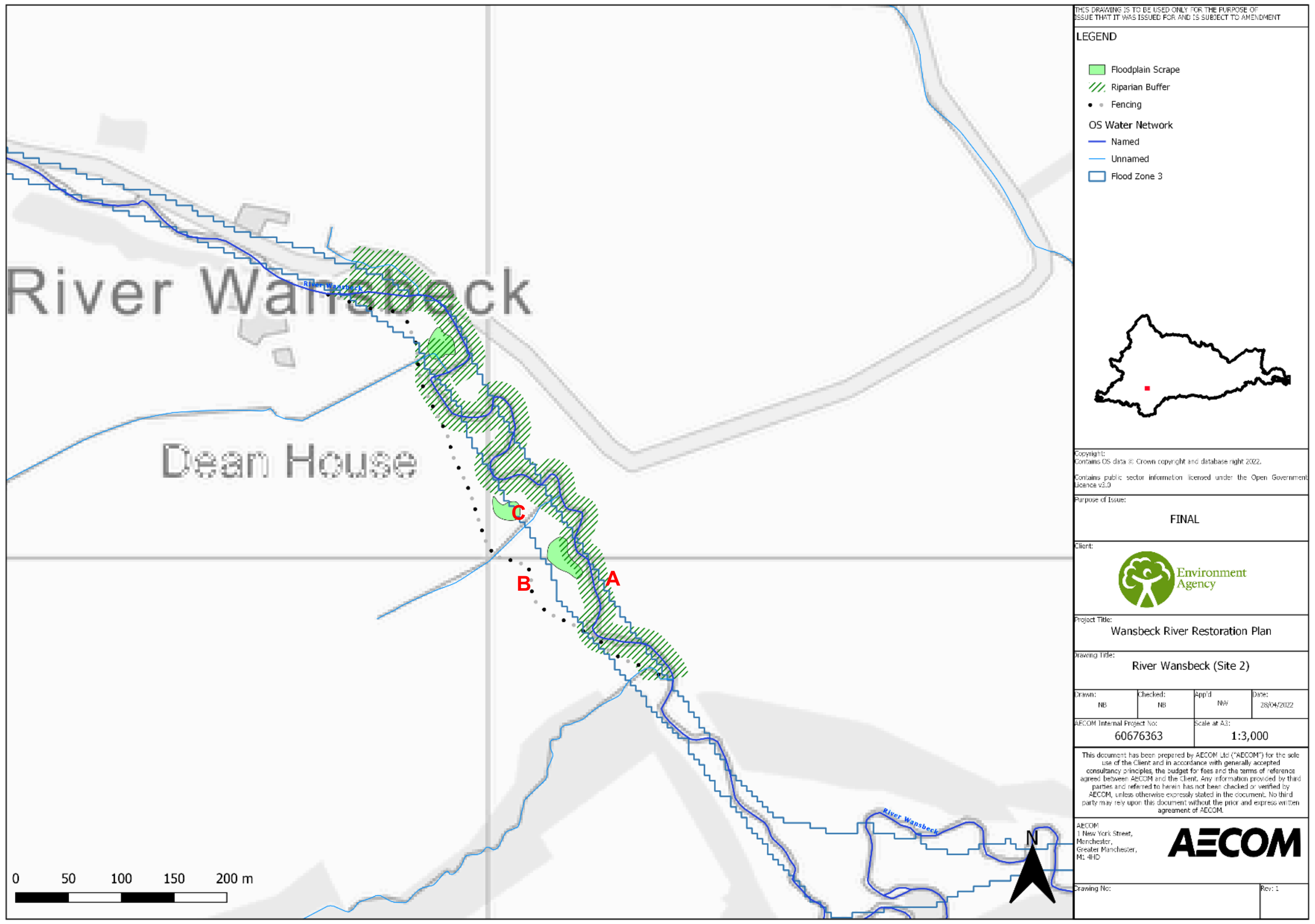


Figure 7-3 Conceptual restoration plan for River Wansbeck (site 2)

Point	Feature	Description
A	Riparian buffer strip	A strip of vegetation would be implanted adjacent to the proposed channel diversion to generate high quality riparian habitat. The feature would comprise a seed mix of appropriate semi-aquatic species.
B	Fencing	Strategic stock fencing to eliminate or reduce livestock access to the floodplain and channel. This would permit self-recovery of floodplain habitat.
C	Floodplain scrapes	Floodplain scrapes are informal excavations in the landscape that provide topographic variance and thus additional niche habitat for a range of flora and fauna. They are simple to implement and cost-effective since they can be left to self-seed.

A. Sinuous channel planform with well-connected floodplain.

B. Typical substrate character comprises coarse gravel material.

C. Limited habitat complexity on the local floodplain.

D. Hydraulic variance and complex bedforms.

E. Laterally well-connected low-lying berm feature.

F. Concrete ford structure impounds flow and sediment and limits longitudinal ecological connectivity.

River Wansbeck (Site 3)

Baseline Characteristics

Channel form

7.23 The River Wansbeck at this location has potentially been realigned at some point in history although if this occurred, it did so before formal Ordnance Survey mapping began in the mid-19th Century. However, a network of palaeochannels that cross the adjacent floodplain suggest the river once exhibited a complex, sinuous, and potentially multi-channel form, but has been confined to a single-thread channel with a depleted floodplain. The existing channel is slightly over-deep further suggesting that it is modified to some degree.

Substrate Conditions

7.24 Substrate of the reach is comprised predominantly of coarse gravels and small cobbles with smaller proportions of sands, fine gravels and small boulders. Coarser material is arranged into a sequence of riffle features while fine material occupies scoured pools and sediment berms at the channel margins that appear to accommodate marginal vegetation.

Flow Conditions

7.25 Flow conditions in the reach are reasonably complex. Pool-riffle sequences give rise to areas of smooth and turbulent flow respectively, whilst the moderately sinuous planform generates localised eddy flows and deep scour pools that contribute to the overall hydraulic variance of the reach. However, this all takes place within a modified single-thread channel, which appears to be somewhat disconnected from its floodplain.

Floodplain Characteristics

7.26 The floodplain is comprised of heavily grazed improved grassland with very little habitat complexity. The aforementioned network of palaeo-features provides small patches of bog; but these are fragmented and account for a small portion of the floodplain area. The palaeo-channels appear to form a bifurcated planform in places. It is unclear how frequently these features are inundated but is likely to be during only extreme flow events, with lower magnitude flows occupying the existing channel for the majority of time. Nevertheless, flood trash was observed within the palaeo-channel system; indicating that they are occasionally activated; however, the habitat they provide is limited and temporary.

Riparian Zone

7.27 The adjacent riparian zone is confined to a narrow strip throughout the reach, although there are fragmented sections of marginal plants and occasional alder trees, in addition to marginal sediment berm features that support plant growth in what is a somewhat over-deepened channel corridor.

Modifications

7.28 As previously described, the channel in this reach has potentially been artificially realigned at some point in history. The site is located adjacent to and just upstream of South Middleton medieval village and open field system – a Scheduled Monument. Channel and floodplain modifications, therefore, potentially date from as early as the 13th Century. In addition, a clear-span bridge structure is situated at the downstream extent of the reach. This has left- and right-bank abutments that extend approximately 2m into the channel. Some minor localised scour has potentially occurred on the left abutment; however, overall, the structure does not appear to significantly affect channel morphology.

Restoration Opportunities

7.29 The degraded nature of the local floodplain at this location and the presence of historical palaeo-channels presents a good opportunity to implement a considerable degree of habitat complexity within a relatively short reach. Encouraging flow onto the floodplain more frequently that at present would generate a complex multi-channel system during elevated flow events. Excavating backwater features and informal scrapes would provide niche floodplain habitat while a high-quality riparian buffer would provide channel shading and habitat for a range of aquatic and semi-aquatic flora and fauna. A conceptual plan of restoration opportunities is shown in Figure 7-4 below.

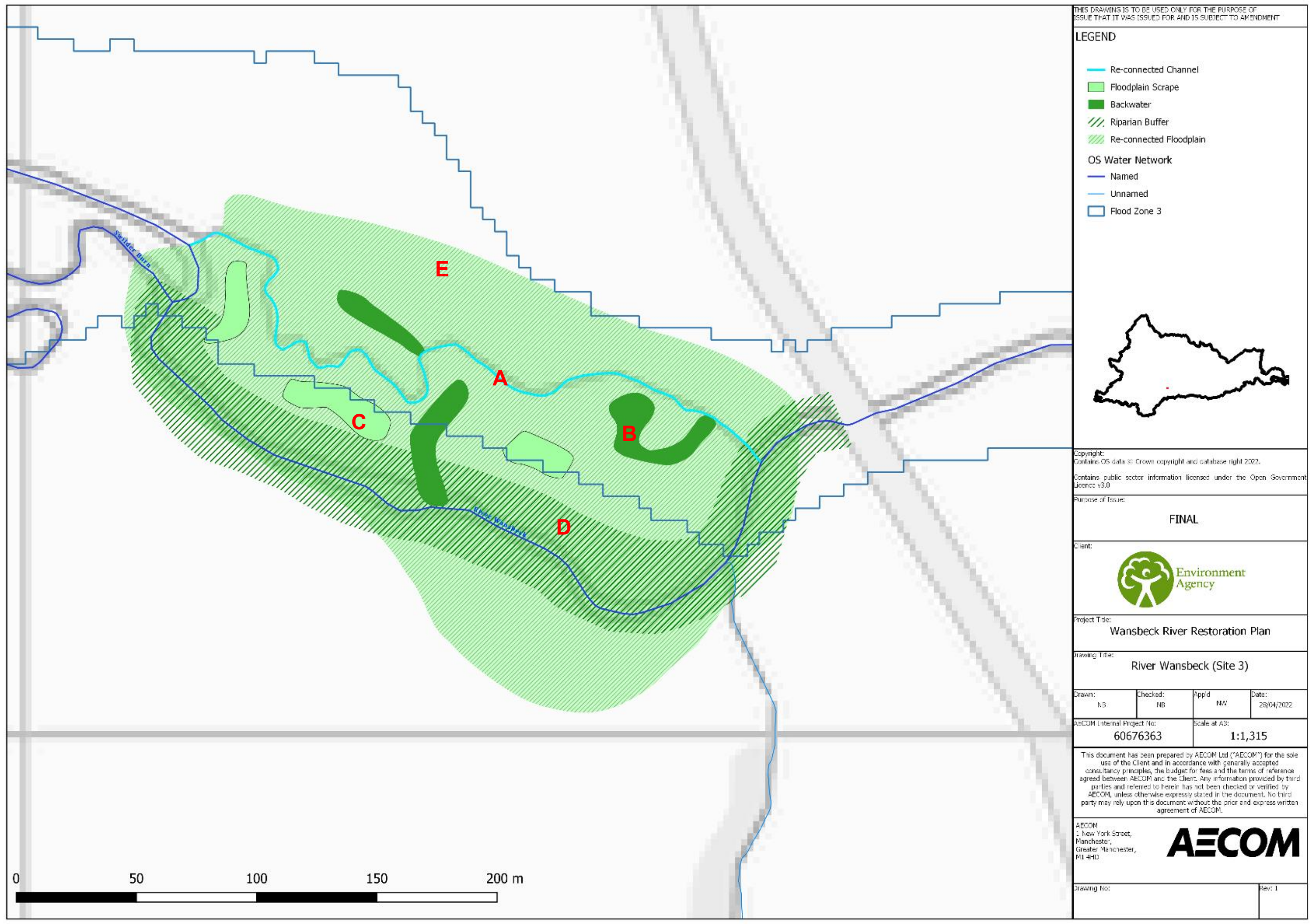


Figure 7-4 Conceptual restoration plan for River Wansbeck (site 3)

Point	Feature	Description
A	Re-connected channel	The former natural course of the channel that is visible in the landscape as relic palaeo-channel forms. Reconnecting these would significantly increase channel length, improve lateral connectivity, and thus, promote restoration of the wider floodplain.
B	Backwater feature	Excavated connected wetland feature that becomes inundated during elevated flows and provides niche habitat to a range of flora and fauna.
C	Floodplain scrape	Floodplain scrapes are informal excavations in the landscape that provide topographic variance and thus additional niche habitat for a range of flora and fauna. They are simple to implement and cost-effective since they can be left to self-seed.
D	Riparian buffer strip	A strip of vegetation would be implanted adjacent to the proposed channel diversion to generate high quality riparian habitat. The feature would comprise a seed mix of appropriate semi-aquatic species.
E	Re-connected floodplain	Indicative re-connected floodplain extent. Improved hydrological connectivity would promote recovery of floodplain and groundwater-dependant habitats.

A. Slightly over-deep channel corridor with low-functioning floodplain.

B. Typical channel substrate.

C. Complex flow structure and bedforms.

D. Disconnected palaeo-channel on low-functioning floodplain.

E. sparse riparian vegetation.

F. Bridge structure with abutments immediately adjacent to the channel.

River Wansbeck (Site 4)

Baseline Characteristics

Channel form

7.30 The River Wansbeck in this reach is sinuous but over-deepened with evidence of extensive management practices such as historical embankment construction and dredging. The channel is indicative of a laterally unconfined active single thread system; however, the formally dynamic nature of the reach has probably been somewhat curtailed both by catchment-wide changes in sediment supply and flow regime, and local changes in land use and physical modification. The natural river corridor is likely to have had a more diverse wetland complex associated with partially connected meander cutoffs and backwaters.

Substrate Conditions

7.31 Channel substrate comprises a significant excess of fine clayey material that chokes the interstitial matrix of coarser gravels. Potential dredging of the channel and removal of coarse loose material, coupled with changes to sediment supply at the wider catchment scale, has resulted in a fairly homogenous bed character. While a few armoured riffle features are present throughout the reach, they are infrequent and confined mostly to the downstream extent.

Flow Conditions

7.32 Flow conditions are similarly homogeneous which is probably a result of extensive modification. Small parcels of turbulent flow exist at the occasional riffle features; however, flow structure is largely dominated by flat, laminar glide and ponded sections. This is promoted by the over-deep, character of the channel which confines flow to a narrow, deep corridor even during elevated flow events, including those exceeding the two-year annual exceedance probability.

Floodplain Characteristics

7.33 The floodplain in this reach is dysfunctional and offers little habitat heterogeneity. Local land use is dominated by improved grassland predominantly used for cattle farming, of which a significant area is covered by historical ridge and furrow. In addition, there are a number of degraded historical flood embankments that serve to further disconnect out-of-bank flow with the floodplain. There are, however, a few very localised patches of bog and wetland habitat towards the downstream extent of the reach, in addition to a handful of low-lying berm features that are more directly connected to the channel than the wider floodplain; however, cattle are still able to access these features, so they offer only minimal habitat benefits.

Riparian Zone

7.34 The riparian zone within the reach is similarly very poor quality, with only a few fragmented patches of vegetation and standalone trees representing the bulk of marginal habitat. The channel has probably been maintained for flood-risk and/or land drainage in recent history which potentially involved removal of vegetation. In addition, the existing intensive agricultural practices that occur across the adjacent floodplain limits the opportunity for regeneration of riparian vegetation, while the over-deep character of the river channel disconnects marginal habitats, thus supporting their degradation.

Modifications

7.35 As described previously the entire reach is the product of anthropogenic modification; however, despite this, there are no significant in-channel features or formal engineered bank protection that limit natural geomorphological processes; however, the channel has been extensively dredged, which may explain the uniform flow character and excess fine sediment that is confined to the over-deep channel, rather than settling onto the floodplain. A dual-span rail bridge is located at the downstream extent of while a former rail embankment gradually encroaches across the floodplain at the downstream extent of the reach. In addition, there is an informal ford crossing and a footbridge in the centre of the reach, but these impart only minimal, localised impacts.

Restoration Opportunities

7.36 This is reach is the largest of the six shortlisted sites, one of the most heavily degraded and, therefore, has greatest potential for extensive river and floodplain restoration. There is an abundance of restoration opportunities that vary in extent and ambition, which, if delivered in their entirety, would amount to full-valley restoration. The predominant opportunity, broadly, is reconnection of the channel with its floodplain. This could be facilitated in a number of ways and at various spatial scales; however, the over-deep character of the channel may present some difficulty in getting flow back onto the floodplain during lower magnitude flood events, and this would require investigation at subsequent design stages if carried forward. To that end, low-lying pseudo-floodplain features could be excavated in order to drop the level of the existing floodplain and create hydrologically well-connected riparian wetlands. The existing floodplain exhibits evidence of historical lateral migration processes in the form of remnant palaeo channel features; however, they offer little habitat benefits given the degree to which the channel-floodplain system has been modified. There is an opportunity to reconnect some of these to create backwater/backswamp habitat by excavating existing river banks to allow higher flows to inundate the features. Similarly, floodplain scrapes, as previously described, would generate topographic variance in the floodplain to create niche habitat and improve vertical connectivity with groundwater.

7.37 It may be possible to manipulate the channel bed at strategic locations with augmented gravel features or large woody material check dams at bed level, in order to raise its level and encourage flow onto the floodplain, as well as generating hydraulic variation and high value habitat. If this were achievable, it would be beneficial to remove a series of historical flood embankments at the upstream end of the reach, which appear to serve little practical purpose and contribute to the over hydrological disconnection between the channel and its riparian zone and wider floodplain.

7.38 The site receives drainage from Middleton Burn – a tributary of the River Wansbeck – which is has also been identified for restoration and would form a sub-branch of the larger restoration site. A conceptual plan of restoration opportunities is shown in Figure 7-5 below.

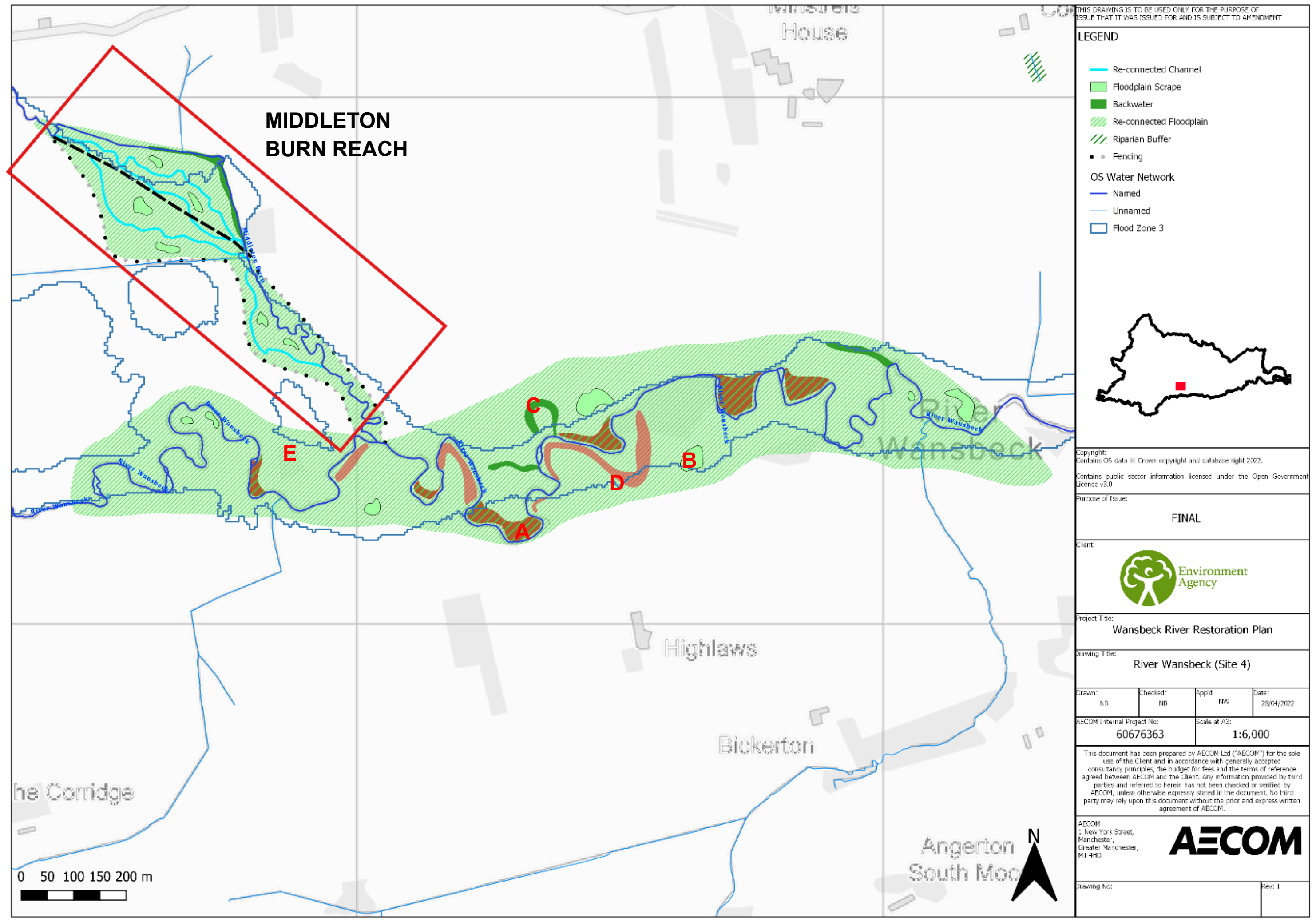


Figure 7-5 Conceptual restoration plan for River Wansbeck (site 4)

Point	Feature	Description
A	Lowered floodplain	Areas of lowered floodplain that provide enhanced connectivity with the channel and reinstate wetland habitats that have been lost as a result of floodplain degradation.
B	Floodplain Scrape	Floodplain scrapes are informal excavations in the landscape that provide topographic variance and thus additional niche habitat for a range of flora and fauna. They are simple to implement and cost-effective since they can be left to self-seed.
C	Backwater	Former river meanders that are reconnected to provide niche habitat
D	Embankment removal	Removal of historical flood embankments to promote lateral flood connectivity and encourage regeneration of floodplain habitat.
E	Reconnected floodplain	Indicative re-connected floodplain extent. Improved hydrological connectivity would promote recovery of floodplain and groundwater-dependant habitats.

A. Grossly over-deep channel corridor.

B. Morphologically diverse riffle unit brought about by wider cross-sectional geometry and low-lying, well-connected lateral berms.

C. Typical laminar flow structure within sinuous channel.

D. Sparse, heavily managed floodplain and riparian zone with obvious livestock issues.

E. Severely degraded riparian zone with evidence of livestock poaching and river bank mass failure processes.

F. Ad hoc and ineffective erosion protection.

Middleton Burn

Baseline Characteristics

Channel form

7.39 Middleton Burn flows through a naturally straight bedrock confined channel before flowing onto an expansive alluvial floodplain just downstream of Middleton Village. However, at some point in history, prior to formalised Ordnance Survey mapping in the mid-19th Century, the channel was realigned to follow a straightened course along a field boundary, presumably to maximise land available for farming. Prior to this, the burn flows across alluvial fan deposits, suggesting that it may have represented a complex multi-channel system that was very well-connected with its floodplain.

Substrate Conditions

7.40 Substrate is predominantly comprised of coarse gravel deposits with smaller proportions of finer silts and sands, and larger cobbles. A handful of pool-riffle unit features were noted throughout the reach which provide some habitat value; however, the channel's straight planform limits hydraulic and morphological diversity.

Flow Conditions

7.41 Flow conditions are likewise influenced by the modified channel, which, as described above, results in diminished diversity of flow types, which are dominated by laminar glide features interspersed with occasional riffle units.

Floodplain Characteristics

7.42 The channel sits at the north-eastern margin of the floodplain in an artificial dog-leg arrangement. This has led to a disconnection between the channel and floodplain, such that practically no floodplain habitat diversity exists. A very obvious network of palaeo-channel features intersect the floodplain, but these support little habitat, other than a few small pockets of bog. The floodplain is particularly degraded towards the downstream extent of the reach, towards confluence with the River Wansbeck. Here, intensive livestock farming has resulted in an extremely homogenous, ecologically poor landscape. Further upstream, the floodplain accommodates rough pasture and grasses due to less intensive grazing pressures. However, recovery of wetland habitat is limited by the disconnect with the watercourse.

Riparian Zone

7.43 The riparian zone is similarly of poor quality; however, there are a small number of inset depositional berms features, comprised of fine cohesive material, that provide a growing medium for marginal and emergent aquatic macrophytes. These also generate localised flow complexity and provide habitat for fish and invertebrates.

Modifications

7.44 Aside from historical channel realignment, there are relatively few modifications to the reach that directly impact its morphological and ecological functioning. The most notable modification is a dual pipe culvert structure (approximately 300mm dia.) that conveys flow under a field access crossing point. The pipes have a depressed invert and natural substrate, and therefore probably do not impeded sediment transport or upstream migration routes; though they are narrow gauge and therefore are likely to surcharge during elevated flow events.

Restoration Opportunities

7.45 The Middleton Burn site would also respond well to floodplain reconnection by diverting the existing watercourse to its form course and creating a complex multi-thread channel system across a restored floodplain. This could be facilitated by blocking the existing channel just downstream of where the former channel was diverted. The newly reinstated channel would require a suitably sized gravel substrate comprising of topographic high points (riffles) and low points (pools) in addition to an enhanced riparian zone with appropriate planting. Sections of the old channel could be left open as swap habitat while the re-connected floodplain could be enhanced with scrape features to niche wetland habitat. The existing bridleway could be retained with the addition of a raised board walk, which would add amenity value. A conceptual plan of restoration opportunities is shown in Figure 7-6 below.

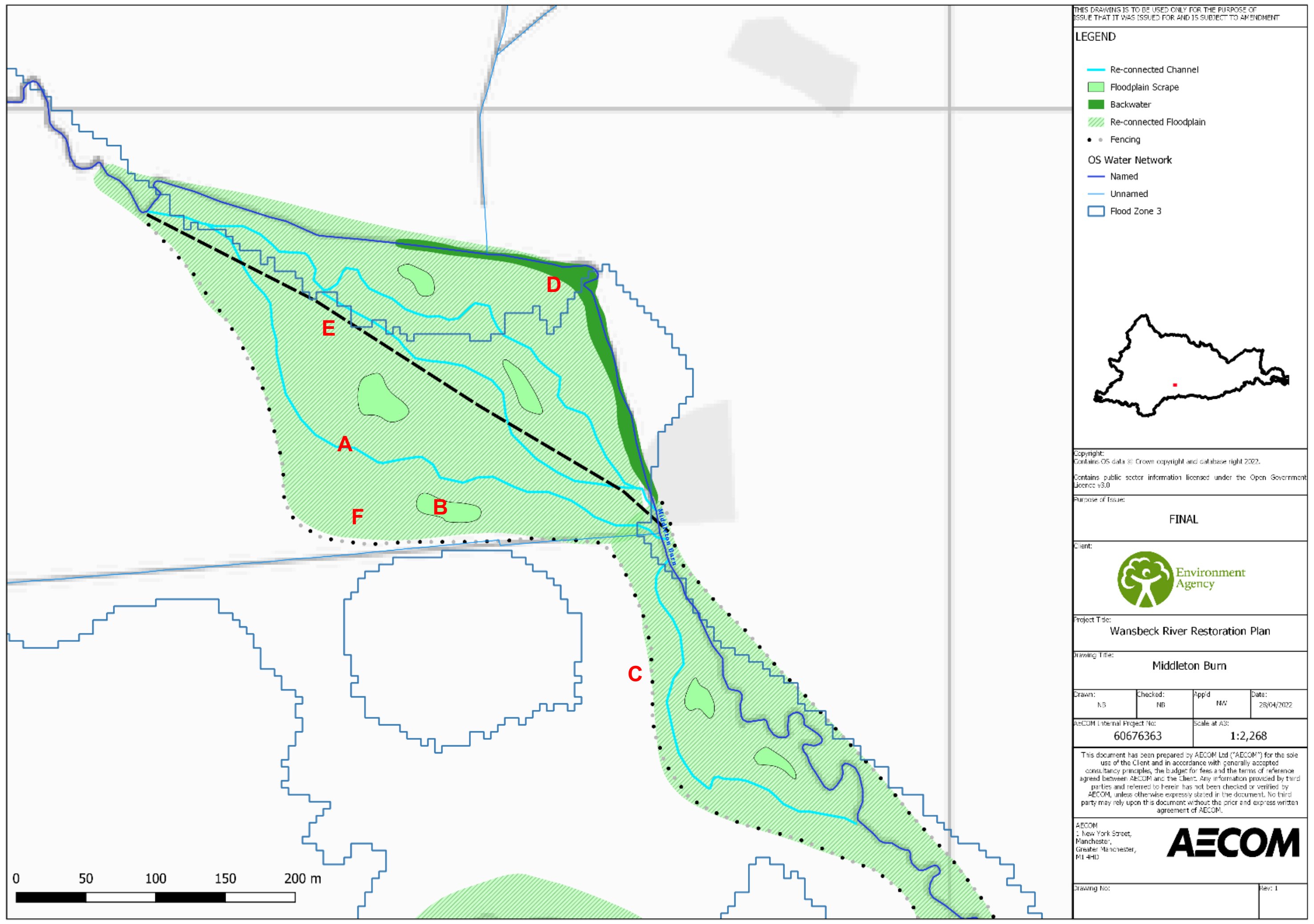


Figure 7-6 Conceptual restoration plan for Middleton Burn

Point	Feature	Description
A	Re-connected channel network	Reinstatement of historical multi-thread channel system across the underlying alluvial fan deposits.
B	Floodplain Scrape	Floodplain scrapes are informal excavations in the landscape that provide topographic variance and thus additional niche habitat for a range of flora and fauna. They are simple to implement and cost-effective since they can be left to self-seed.
C	Fencing	Strategic fencing to limit or eliminate livestock access to the restored floodplain and channel network.
D	Backwater	
E	Raised boardwalk	Raised boardwalk to retain existing bridleway and add considerable amenity value. Additional viewing platforms and information boards could be added to connect the public with nature.
F	Reconnected Floodplain	Indicative reconnected, high-functioning floodplain.

A. Straightened planform of Middleton Brun.

B. Coarse cobble and gravel substrate.

C. Vegetated sediment berm feature with localised hydraulic variance.

D. former course of the watercourse across a low-functioning floodplain.

E. Homogenous floodplain and riparian habitat.

F. Dual pipe culvert structure.

Tributary of Hart Burn

Baseline Characteristics

Channel form

7.46 The unnamed tributary of Hart Burn is essentially a heavily modified agricultural drain that offers very little habitat benefit or variation. The channel is mostly straight and grossly over-deep, presumably as a consequence of a long history of maintenance, such as regular dredging, and is a typical example of small agricultural watercourses within the catchment. The gradient of the watercourse is moderate (>3%) through the upper reaches where the channel is particularly entrenched, but transitions to low gradient (<1%) in the lower reaches where a series of habitat ponds have been created by the landowner[4].

7.47 Historical mapping and aerial LiDAR offer little evidence of the original, unmodified character of the watercourse, but it may have represented a diffuse headwater system with no formal channel before being aggregated to a single drainage ditch in order to drain the local land for agriculture.

7.48 Topography becomes less constrained just downstream of an unnamed B-road where the channel is completely straight. Underlying superficial geology at this location is comprised of extensive alluvial deposits suggesting a former fluvial influence; but this area is now occupied by pasture with the channel running completely straight in an over-deep ditch.

Substrate Conditions

7.49 Channel substrate is comprised predominantly of silt and fines through the upstream reach, and coarser sands and gravels towards the downstream reach where there is noticeably more flow. There are a few small, embryonic riffle features where coarse gravel accumulations form locally topographic high points; however, the modified nature of the channel restricts development of bedforms.

Flow Conditions

7.50 On the day of survey (24 April 2022) the uppermost reach of the channel was mostly dry, with a few pockets of standing water. Flow gradually accumulated further downstream, presumably where there is greater baseflow influence. Flow variance is fairly limited, but a few riffle features offer some localised habitat diversity.

Floodplain Characteristics

7.51 The channel is laterally confined and has little to no floodplain in the upper reaches. Further downstream, topography opens out into an expansive basin feature that possibly once accommodated a wetland habitat but has since been drained for agricultural purposes. Local land use is dominated by herbal rich pasture which has been implemented by the Middleton North Estate as part of their ongoing commitment to ecologically sympathetic land management practices and habitat creation.

Riparian Zone

7.52 The channel's riparian zone is dominated by overgrown terrestrial grasses, brambles and scrub. The over deep geometry of the channel restricts development of a high-quality riparian zone and assemblages of aquatic macrophytes. However, towards the downstream reaches, a series of habitat ponds that sit adjacent to and are fed by the watercourse offer significant habitat potential. These are fairly new features installed by the Middleton North Estate but are expected to mature and 'green-up' over the coming years, thereby offering a mosaic of well-established, high-quality riparian wetland.

Modifications

7.53 As described, the watercourse is the product of a long history of modification; however, there are a number of culvert crossings that provide vehicular access to fields. These potentially impede flow, sediment transfer and ecological connectivity.

[4] https://middleton-north.co.uk/ - Accessed April 2022

Restoration Opportunities

7.54 The Tributary of Hart Burn site has the fewest recommended measures but offers significant potential as a template for small watercourse improvements across the catchment. The proposals include installation of 'leaky wood dam' features within the upper reaches of the watercourse to slow flow and downstream distribution of fines and nutrients. Towards the downstream extent of the reach, a leaky dam feature is proposed to encourage flow onto the low-lying basin feature and re-instate a wetland habitat where topography permits. The intention of these measures would be to demonstrate how simple enhancements applied at the catchment-scale could contribute significantly to Water Framework Directive objectives.

7.55 To this end, it is envisaged that the Middleton North Estate – strong advocates of ecologically optimised land management practices – and other likeminded landowners could work towards changing attitudes within the agricultural sector by installing very simple, yet highly effective measures to curtail the distribution of harmful diffuse pollution and sediment run-off across the catchment. A conceptual plan of restoration opportunities is shown in Figure 7-7 below.

Figure 7-7 Conceptual restoration plan for Tributary of Hart Burn

Point	Feature	Description
A	Leaky Dam	Strategically placed log-jam features that impede flow during storm events and prevent rapid runoff of sediment.
B	Restored wetland	Reconnected basin facilitated by leaky dam at the downstream extent.
C	Fencing	Stock fencing to prevent or limit access of livestock to the restored wetland.

A. Over-deep cross-sectional form.

B. Fine sediments with coarser material arranged into a riffle feature.

C. straight, over-deep channel within heavily managed agricultural setting.

D. flow mixing with an adjacent stream. Coloured water is joining the Tributary of Hart Burn from the south.

E. Dense scrub vegetation comprises the channel's riparian zone.

F. Historical obsolete ford crossing.

8. Deliverability of Works and Indicative Costings

8.1 It is difficult to assign specific costs to the restoration measures presented above: these would be developed at subsequent stages of the design process as more detail becomes available about each site. It is possible, however, to estimate high-level 'rough order of magnitude' (ROM) costs based on published information (Environment Agency, 2015) and previous restoration schemes (see RRC, 2014). To that end, Table 8-1 presents indicative costs and deliverability of each restoration measure. Deliverability refers to the ease with which each measure could be implemented and is assigned to one of the three general levels:

Do Nothing

- Allow self-recovery, such as maintaining riparian buffers or allowing arable fields to transition to mixed grassland
- This fits with the brief in terms of allowing time for assisted natural recovery before any further intervention is undertaken.
- landowner and tenant farmer can implement immediately

Quick Win

- Low engineering effort for high gain – e.g., embankment removal, leaky dam creation
- Also fits with the brief in terms of allowing time for assisted natural recovery before any further intervention is undertaken
- Some consulting services, planning and design needed
- Some stakeholder engagement needed
- Rural site / no risk receptors

Ambitious Measure

- Major interventions that require detailed study, greater investment for greater long-term benefit
- Need extensive planning, modelling, permitting and design
- Need ongoing stakeholder/regulator engagement
- Need time to demonstrate benefits to landowners or tenant farmers to gain buy-in
- Other risk receptors to consider

Table 8-1 Deliverability and Indicative Costings

Shortlisted Site	Restoration measure	Deliverability	ROM Cost
River Wansbeck (site 1)	• Re-connected palaeo-channel • Wetland/wet woodland • Floodplain scrape • Open backwater • Riparian buffer strip • Re-connected floodplain	• 3 • 2 • 2 • 2 • 1 • 3	• High • Medium • Low • Medium • Low • Low
River Wansbeck (site 2)	• Riparian buffer strip • Fencing • Floodplain scrapes	• 1 • 2 • 2	• Low • Low • Low
River Wansbeck (site 3)	• Re-connected channel • Backwater feature • Floodplain scrape • Riparian buffer strip • Re-connected floodplain	• 3 • 2 • 2 • 1 • 3	• High • Medium • Low • Low • Low

Shortlisted Site	Restoration measure	Deliverability	ROM Cost
River Wansbeck (site 4)	• Lowered floodplain • Floodplain Scrape • Backwater • Embankment removal • Reconnected floodplain	• 3 • 2 • 2 • 2 • 3	• High • Low • Medium • Medium • Low
Middleton Burn	• Re-connected channel network • Floodplain Scrape • Fencing • Backwater • Raised boardwalk • Reconnected Floodplain	• 3 • 2 • 2 • 2 • 2 • 2	• High • Low • Low • Medium • Medium • Low
Tributary of Hart Burn	• Leaky Dam • Restored wetland • Fencing	• 1 • 1 • 2	• Low • Low • Low

9. Conclusions

9.1 Most of the WFD surface water bodies that comprise the River Wansbeck catchment are failing their legislative objectives. The primary source of degradation is derived from catchment-wide intensive agriculture which, historically, has resulted in extensive physical modification of river channels through straightening, dredging, and embanking. Floodplains have also become severely degraded as a result of intensive land drainage activity dating back to the Medieval Period, as evidenced by widespread ‘ridge and furrow’ features within the landscape. Contemporary, post-war agricultural practices have led to intensification of diffuse pollution and sediment runoff which has severely degraded riverine biodiversity across the catchment.

9.2 However, this study has demonstrated that there is an abundance of river restoration opportunities throughout the catchment at a range of spatial scales. By far the most prevalent opportunity is implementation of riparian buffer zones to intercept runoff and provide marginal habitat. However, this measure in isolation is insufficient to contribute to WFD objectives; rather, it requires extensive water body-scale implementation to succeed.

9.3 The shortlist of river restoration options predominantly comprises ambitious reach-scale opportunities that would contribute significantly to WFD objectives. The restoration options are intended to restore natural geomorphological processes that provide the template for in-channel and floodplain habitat diversity and thus would have knock-on benefits to a range of ecological receptors, as well as having considerable amenity value. In addition, the restoration options provide parcels of enhancement between existing higher quality reaches and therefore co-inside with the Habitat Network Modelling undertaken by AECOM as part of the Wansbeck Habitat Restoration and Creation Plan.

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