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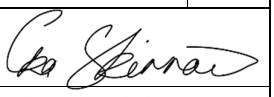
Author(s)	Dr Grace Skirrow, cbec eco-engineering UK Ltd		
Technical & Commercial Reviewer	Dr Lynsey MacLeary, cbec eco-engineering UK Ltd		
To	John Furlong, Ardhuncart Estate		
Project	River Don, Ardhuncart Estate Large Wood Survey		
Subject	Hydromorphic assessment and design recommendations for large wood structures on the River Don and Mossat Burn on the Ardhuncart Estate		

1. INTRODUCTION

cbec eco-engineering UK Ltd was commissioned by Allathan Associates to undertake a hydrogeomorphic assessment of the mainstem River Don and Mossat Burn tributary within the Ardhuncart Estate, to produce design recommendations for large wood structures (LWS) and porous log jams (PLJ). This report follows a scoping study, previously undertaken by cbec, which delivered an options long list of potential restoration measures along the River Don that offer ecological and habitat improvements and natural flood risk management benefits[1]. The implementation of LWS forms part of a multiple-technique restoration approach that is currently under consideration. Like many catchments, the Don catchment has little tree cover, resulting in a general lack of accumulation of natural large wood in the watercourse. The impacts of this affect in-channel habitat through reduced in-channel diversity and a lack of thermal refugia for fish. To address this, the present project aims to provide an immediate source of large wood to improve habitat in the River Don and Mossat Burn, with a future supply of large wood to be provided as a result of riparian tree planting across the Estate.

The implementation of the LWS is intended to 'kick-start' natural river processes with the aim to achieve the following objectives:

- increase physical channel heterogeneity in terms of channel morphology and sedimentology, leading to improved biodiversity;
- optimise in-stream habitat to support the spawning and rearing of salmonids;
- contribute to climate resilience by slowing water movement, reducing flood peaks and providing cooler refuge areas (i.e. in-channel cover) for aquatic life as temperatures rise under climate change.

Implementation of LWS enhances geomorphic process by encouraging localised bar development and associated bank erosion to induce the natural recruitment of alluvial material and, over time, large wood to the channel. Large wood also encourages bed erosion and the development of scour pools around the woody material, offering additional refuge habitat. During the walkover, potential for 'bar apex' and 'medial' LWS (examples/ indicative illustrations of these structures are provided in Table

[1] cbec eco-engineering UK Ltd. 2023. River Don Scoping Study. Prepared for Ardhuncart Estate – Project No. 2150530

apex' and 'medial' LWS (examples/ indicative illustrations of these structures are provided in Table 1.1) was assessed with reference to the geomorphic condition of each watercourse. Both structure types encourage and/ or enhance the natural fluvial processes of sediment erosion and deposition, thereby driving enhanced physical evolution of the channel.

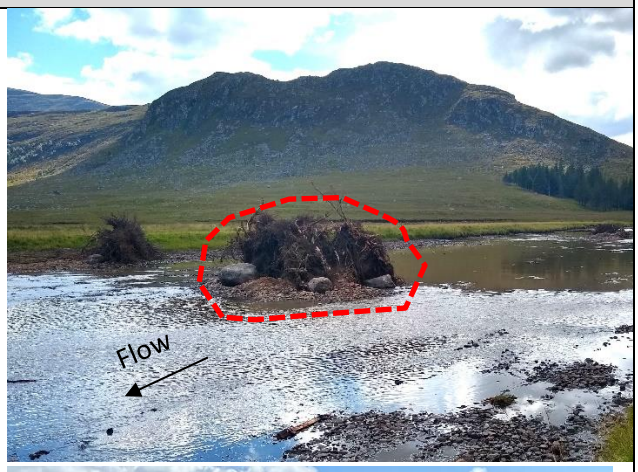
Bar apex structures are typically attached to the bank on the insides of bends just downstream of their apex and are recommended to encourage the further development of existing proto-alluvial bar features (i.e. where there is evidence of some degree of emergent sediment storage) and scour pools and, through deflection of flow towards the opposite bank, enhance the recruitment of sediment (i.e. through bank erosion) and natural large wood (i.e. where trees are currently situated close to the channel bank edge). Medial structures are located mid-channel and are typically proposed in wider, uniform sections of channel to enhance flow diversity around these features, with implications for enhanced geomorphic process.

The geomorphic survey (see Section 3) identified sixty-eight beneficial locations for the installation of LWS. Beneficial locations either have potential to promote habitat improvements through enhancing natural geomorphic processes, or (where potential for geomorphic work is limited) to provide simplified habitat benefits such as in-channel cover and shelter. Each location has been assigned a priority rating of high, medium or low in relation to its potential for locally increasing stream complexity, habitat diversity and in-channel cover, while also taking into account the overall spatial distribution of structures throughout the study extent and the presence of any constraints within the vicinity.

It is understood that implementation may be dictated by the availability of funding, suitable materials (i.e. number and size of wind felled trees available), safe machinery access and ecological or archaeological constraints (e.g. avoiding disturbance to prime Atlantic Salmon spawning/ juvenile habitats and locations utilised by freshwater pearl mussels). A combination of these factors may result in certain reaches being prioritised for implementation over other sections. Therefore, it is hoped that the sixty-eight structure locations identified within this report will provide the project group with some flexibility in achieving their implementation target.

The potential for each structure to encourage the future (natural) recruitment of large wood has not been considered explicitly here. However, areas in which trees are currently interacting with the flow have been highlighted on the maps provided here. Additionally, the locations of the LWS implemented as part of this project can be used to guide future riparian planting. The implementation of the structures is discussed further in Section 3.

Table 1.1 Examples of large wood structures and porous log jams.

Large Wood Structures	
Bar Apex	**Medial**
	
	

1.1 STUDY AREA AND SETTING

The River Don catchment drains an area of 1,318 km^2 in Aberdeenshire. Sourced from the northeast Cairngorm Mountains, the main stem of the river flows eastward to Aberdeen. The study area, on the Ardhuncart Estate, is located along the middle course of the River Don, in a partially confined valley setting where floodplain space is variable owing to topographic controls. Four tributaries join the main stem of the River Don within the study area: the Culsh Burn, Auld Water, Ferney Brae and Mossat Burn. This assessment focussed on the River Don and the Mossat Burn tributary. The survey extents assessed for LWS potential within the Ardhuncart Estate are summarised in Table 1.2 and illustrated in Figure 1.1.

Table 1.2 Reaches surveyed during the LWS walkover.

Reach	Upstream Extent		Downstream Extent		Length (~km)
	OS NGR	Description	OS NGR	Description	
River Don	NJ 47345 16313	Gateside, upstream extent of River Don within the Ardhuncart estate boundary	NJ 47345 16313	Confluence with Mossat Burn, downstream extent of River Don within the Ardhuncart estate boundary	4.16
Mossat Burn	NJ 48506 19001	Upstream extent of Mossat Burn within the Ardhuncart estate boundary	NJ 47345 16313	Confluence with Mossat Burn, downstream extent of Mossat Burn within the Ardhuncart estate boundary	0.87
				Total	5.03

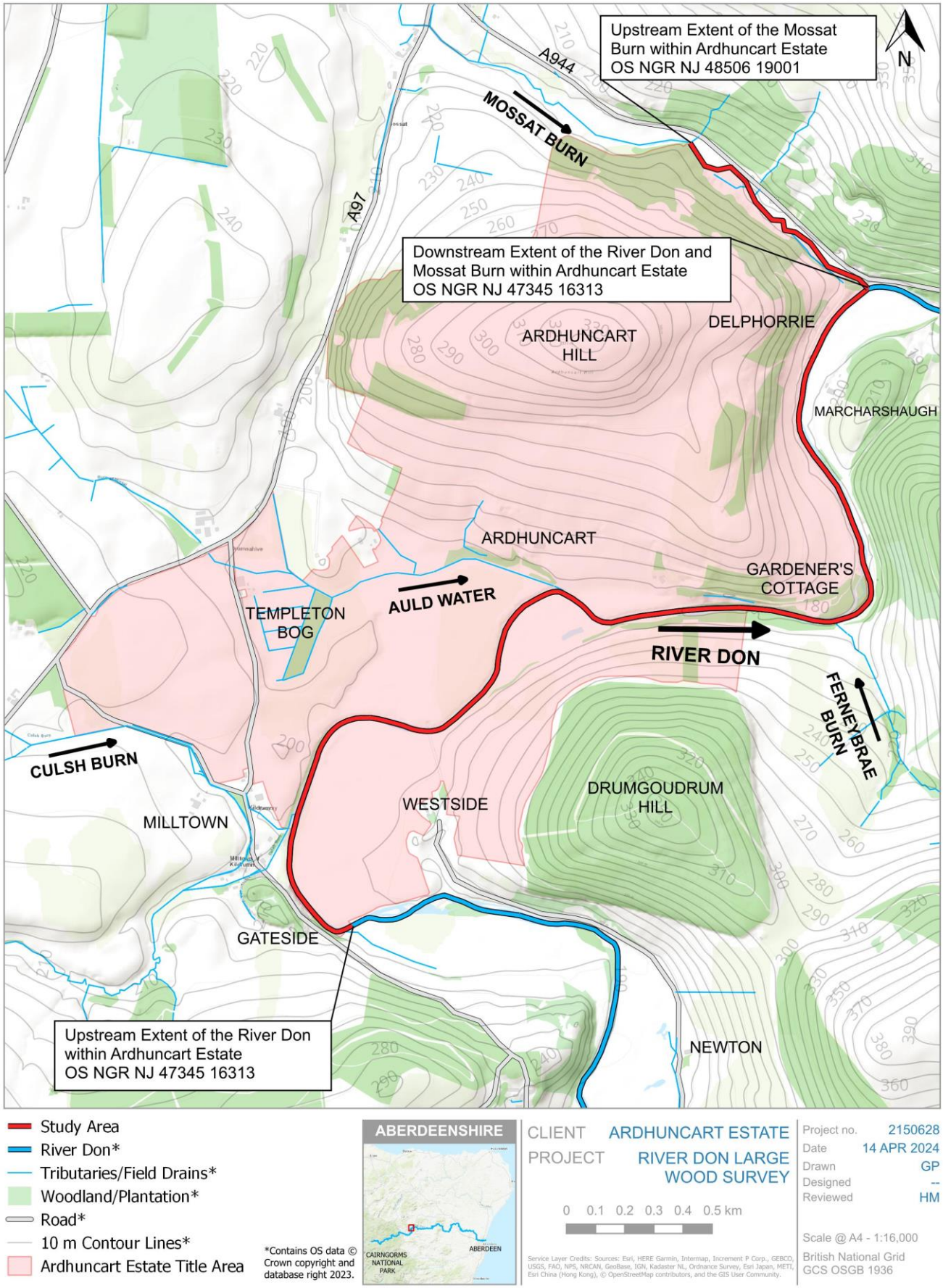


Figure 1.1 Overview map showing locations within the Ardhuncart Estate being considered for LWS implementation. *Contains OS data © Crown copyright and database 2024.

2. GEOMORPHIC SURVEY

2.1 METHODOLOGY

cbec undertook a walkover survey of the three study reaches between 7th and 8th May 2024 to identify suitable locations for the different types of LWS/ PLJ. Survey conditions were dry; water levels were slightly elevated following recent heavy rain but still within the normal survey range, such that bed and bar forms were visible during the survey.

All suitable LWS locations were recorded and geo-referenced during the survey using a mobile GIS platform (QField) with integral GPS capability and post processed using desktop GIS software (ArcGIS and QGIS). Table 2.1 provides a summary of the number and priority level of potential LWS locations identified during the walkover.

Table 2.1 Surveyed LWS/ PLJ locations by reach.

Reaches	Length (~km)	Large Wood Structures				
		Priority			Total	Structure Numbers
		High	Medium	Low		
River Don	4.16	13	21	9	43	D1 to D43
Mossat Burn	0.87	14	6	5	25	M1 to M26
Total	5.03	27	27	14	**68**	

The following information has been provided for each proposed structure (see Appendix A):

- structure reference number, ordered numerically working downstream, with the numbering split into the two different survey areas;
- structure location, given as an easting and northing (x, y);
- type of structure, indicating the location/ type of installation of the large wood across the channel (i.e. left bar apex, right bar apex, medial LWS);
- priority level, assessed in relation to the degree of geomorphic or ecological benefit that could be realised through installation of the structure, with consideration of constraints;
- additional comments, including reasons for site selection, potential benefits for geomorphic and habitat diversity and potential constraints;
- annotated photographs illustrating the direction of flow (blue arrows) and the proposed locations of root plates for the LWS (yellow arrows).

The prioritisation of the proposed locations was undertaken based on conclusions from field observation and GIS analysis. Proposed locations were assigned 'High' priority where the channel morphology was observed to be relatively homogeneous but with evidence of emergent proto-alluvial bar forms and few constraints. Moderate priority was assigned to locations in which some habitat diversity was already present at or near the location, but where there is considered to be good

potential to enhance the extent or quality of existing features. Locations were assigned a Low priority where the channel was already reasonably geomorphologically diverse but where existing alluvial features could be further enhanced or where in-channel cover could be provided by large wood. Areas already exhibiting high bed roughness (i.e. as a result of very coarse substrate) were assigned a lower priority than those without (since LWS would exert a proportionally lower influence in the presence of boulders that at sites without existing roughness).

Logistical issues, such as ease of access/ installation and the availability of trees and boulders locally, were not explicitly considered in the ranking process. However, the table includes comments on these factors and other constraints where appropriate, and the options maps provided indicate the locations of wooded/ forested areas that could be used to supply trees for construction. The identification of appropriate LWS locations has focused primarily on geomorphological improvements to restore natural form and function to the watercourse. Existing freshwater pearl mussel and salmonid habitats were not explicitly considered when assigning rankings. However, structures have been proposed primarily in more homogeneous sections, avoiding areas in which spawning is likely to occur (e.g. riffles). Therefore, it is recommended that the proposed geomorphologically beneficial locations should be cross-referenced with ecological, archaeological and other datasets of protected sites within the Estate to decide upon a shortlist of structures to take forward to construction.

2.2 SUMMARY OF GEOMORPHIC CHARACTERISTICS AND LWS

2.2.1. River Don

The 4.16 km long reach of the River Don that flows through Ardhuncart Estate is a wide (>20 m) and sinuous river set within a partially confined valley, dictated by topographic controls. Accommodation space is greatest in the upper section of the reach, while the channel is more confined downstream of the confluence with the Auld Water (NJ 48068 17454), particularly in the vicinity of Ardhuncart Lodge (NJ 48701 17405). River banks are generally stable, secured with rock armour bank protection and/ or vegetation, and localised sediment supply is subsequently limited. However, infrequent sections of bank erosion expose erosible bank material comprising beds of alluvial sand and sand and gravel; burrows were evident during the survey, demonstrating the existing habitat value (likely for sand martin or water vole). Channel geometry (and therefore flow morphology) is homogeneous along most of the reach, which is dominated by glides and pools. Depositional features including alluvial bars and riffles are present in isolated sections local to a supply of sediment (i.e. bank erosion or tributary inflow). An embankment runs parallel to the channel on the river left floodplain, between Jock Reid Pool (NJ 47327 17019) and the confluence with the Auld Water (NJ 48068 17454), which acts to contain flood flows within the channel and mitigate flood risk to the surrounding floodplain farmland. This embankment has repeatedly been breached at Jock Reid Pool, including during recent flood flows, which has reconnected the floodplain to the channel. Natural floodplain features have begun to recover, including: the deposition of sediment and large wood material (LWM), and the formation of a pond. Riparian vegetation is generally simple and underdeveloped as a habitat. Dominated by grasses and shrubs (e.g. broom), the riparian corridor provides little cover over the channel or opportunities for fish to shelter from predators (i.e. from in-channel root structures and over hanging branches); tree cover is limited to isolated single trees or clusters of trees along the majority of the reach.

The key benefits to be gained from LWS along the River Don reach are: improvements in-channel habitat by increasing the morphological diversity (i.e. flow types and bed forms) in the channel; and provision of in-channel cover and shelter. Locations and types of LWS were determined based predominantly on their potential for promoting geomorphic work and habitat benefits. However, a number of constraints were identified that could impact the construction of and/ or potential to achieve the aims of the LWS. Extrinsic constraints (e.g. construction access) informed the prioritisation of LWS, but it is recommended further shortlisting is carried out with closer consideration for site-specific priorities/ constraints. The constraints pertaining to the River Don reach are summarised below.

- There is limited scope for encouraging lateral adjustment of the channel because of the close proximity to assets, including access tracks, bridges, fences, Ardhuncart Lodge and buildings, Delphorrie Lodge and buildings, Macharshaugh buildings and embankments. Consequently, medial structures are the preferred LWS type as these promote a lesser degree of lateral adjustment than bar apex LWS. Where bar apex structures are proposed, structures are recommended to be installed closer to the banks than is standard (see Section Sizing of Structures3.1.1), extending up to one quarter of the way into the active channel to soften the deflection of flow towards the opposite bank.
- Channel depth exceeds that which is feasible for the installation of medial LWS along much of the reach. Therefore, bar apex structures were proposed where medial

structures were not feasible. As detailed above, where bar apex structures are proposed, structures are recommended to be installed closer to the banks than is standard, extending up to one quarter of the way into the active channel to lessen the degree to which flow is deflected to the opposite bank.

- Spawning habitat and river bank burrows were identified, providing existing habitat value. Where LWS are proposed close to these locations, further consideration is recommended regarding the prioritisation and impact on the site-wide presence of existing habitat.
- Access constraints may impact the construction of some LWS, particularly (but not limited to) the section downstream from Gardeners Cottage (NJ 49040 17534) to the bridge opposite the Macharshaugh buildings (NJ 48923 18261). There is a steep gradient from the access track to the river left and right banks, and limited areas of flat ground to serve as working areas. There may be potential to overcome these constraints with the use of long reach machinery. Furthermore, a marginal wetland area is present alongside the River Don, located at NJ 49108 17582. Bog mats (or similar) maybe be required for construction access.
- Land ownership of the River Don channel, banks and/ or floodplain along the reach is split between Ardhuncart Estate and another landowner, which may impact the implementation of some of the proposed LWS. There are two specific sections of channel for which land ownership is divided: from the upstream extent of the surveyed reach (NJ 47345 16313) to the confluence with the Culsh Burn (NJ 47141 16644); and from immediately downstream of Ardhuncart Lodge (NJ 48701 17405).

Locations identified as appropriate for the implementation of LWS and additional opportunities for river habitat improvements within the River Don are presented in Figure 2.2 to Figure 2.6. Full details of each structure are provided in Appendix A.

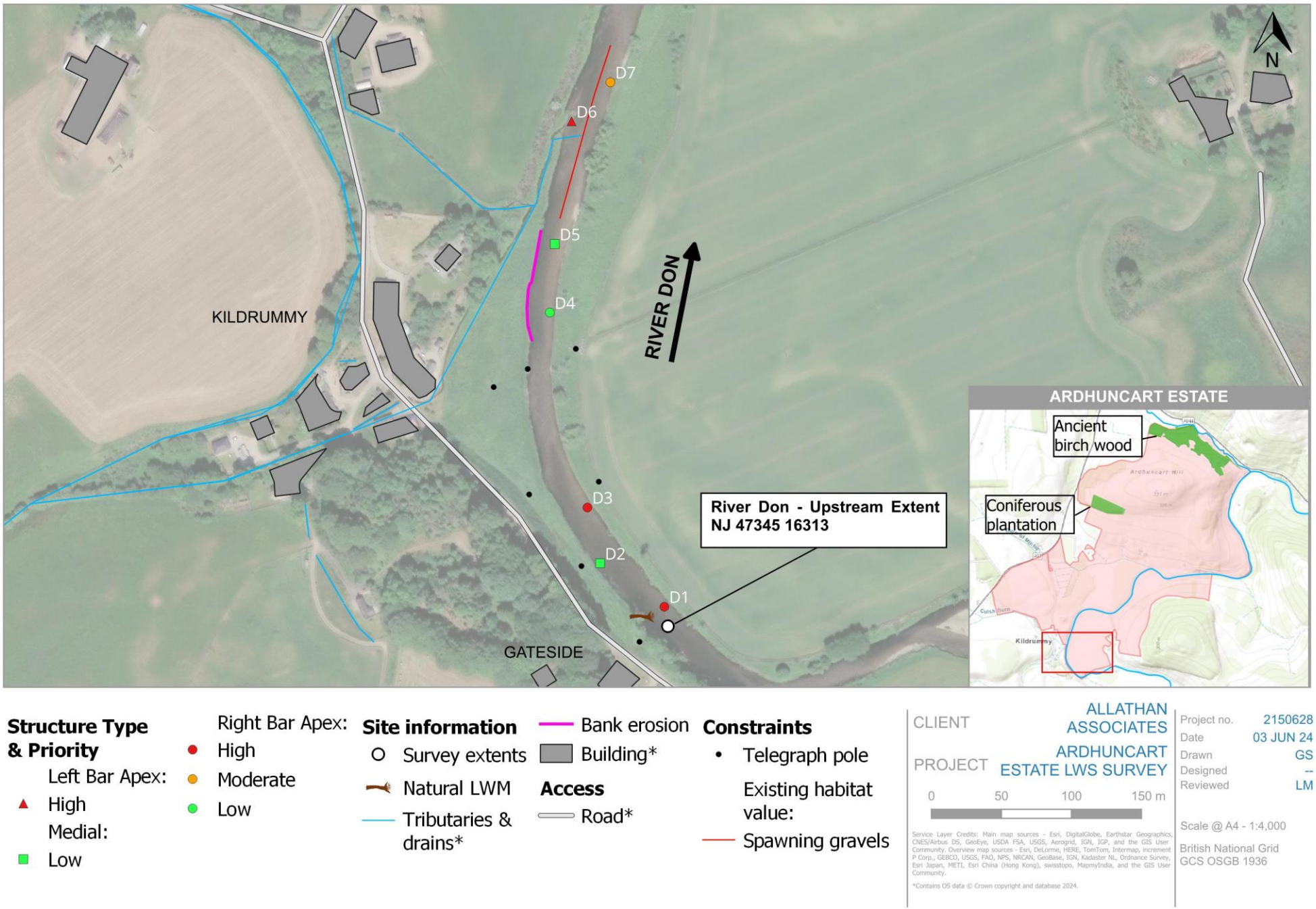


Figure 2.1 Proposed LWS locations along the River Don, Kildrummy (D1 to D7).

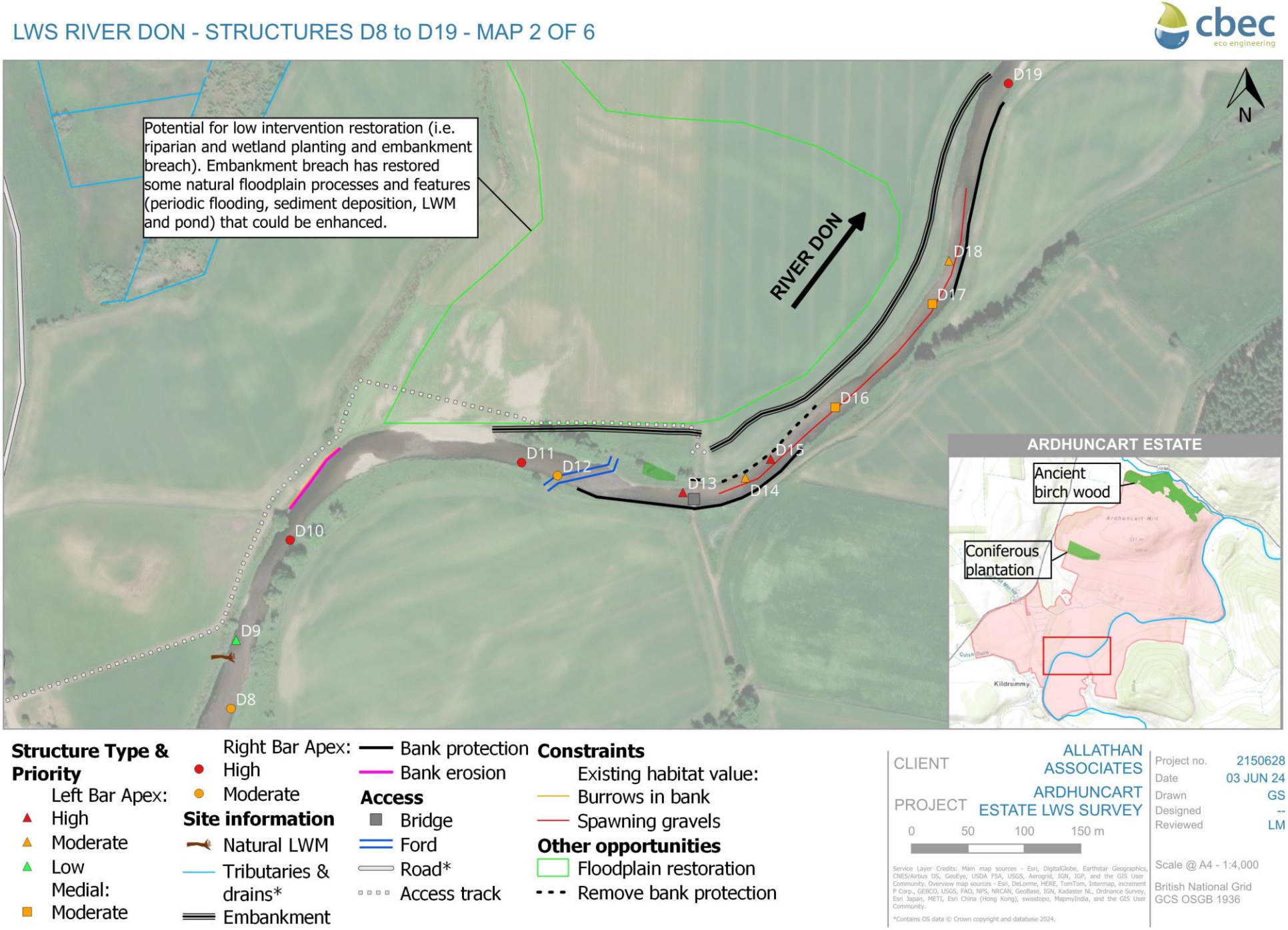
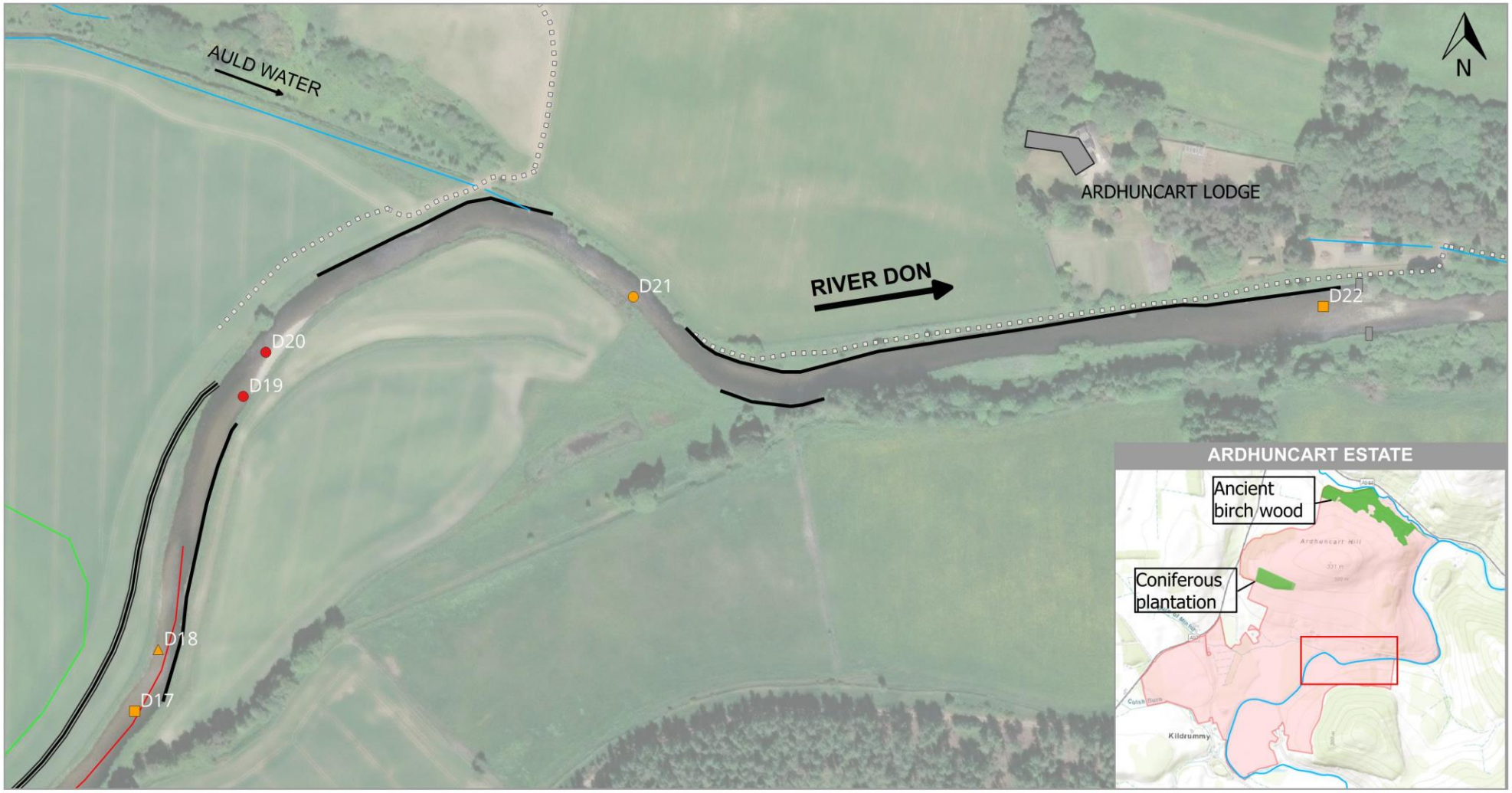


Figure 2.2 Proposed LWS locations along the River Don, Jock Reid Pool vicinity (D8 to D19). Note that boulders for ballast can be sourced from the removal of bank protection.



Structure Type & Priority
Left Bar Apex:
- Moderate

Medial:
- Moderate

Right Bar Apex:
- High
- Moderate

Site information
- Tributaries & drains*
- Embankment
- Bank protection

Access
- Access track

Constraints
Existing habitat value:
- Spawning gravels
- Building*

Other opportunities
- Remove concrete bollards
- Floodplain restoration

CLIENT ALLATHAN ASSOCIATES

PROJECT ARDHUNCART ESTATE LWS SURVEY

0 50 100 150 m

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Figure 2.3 Proposed LWS locations along the River Don, Auld Water and Ardhuncart Lodge vicinity (D17 to D22).

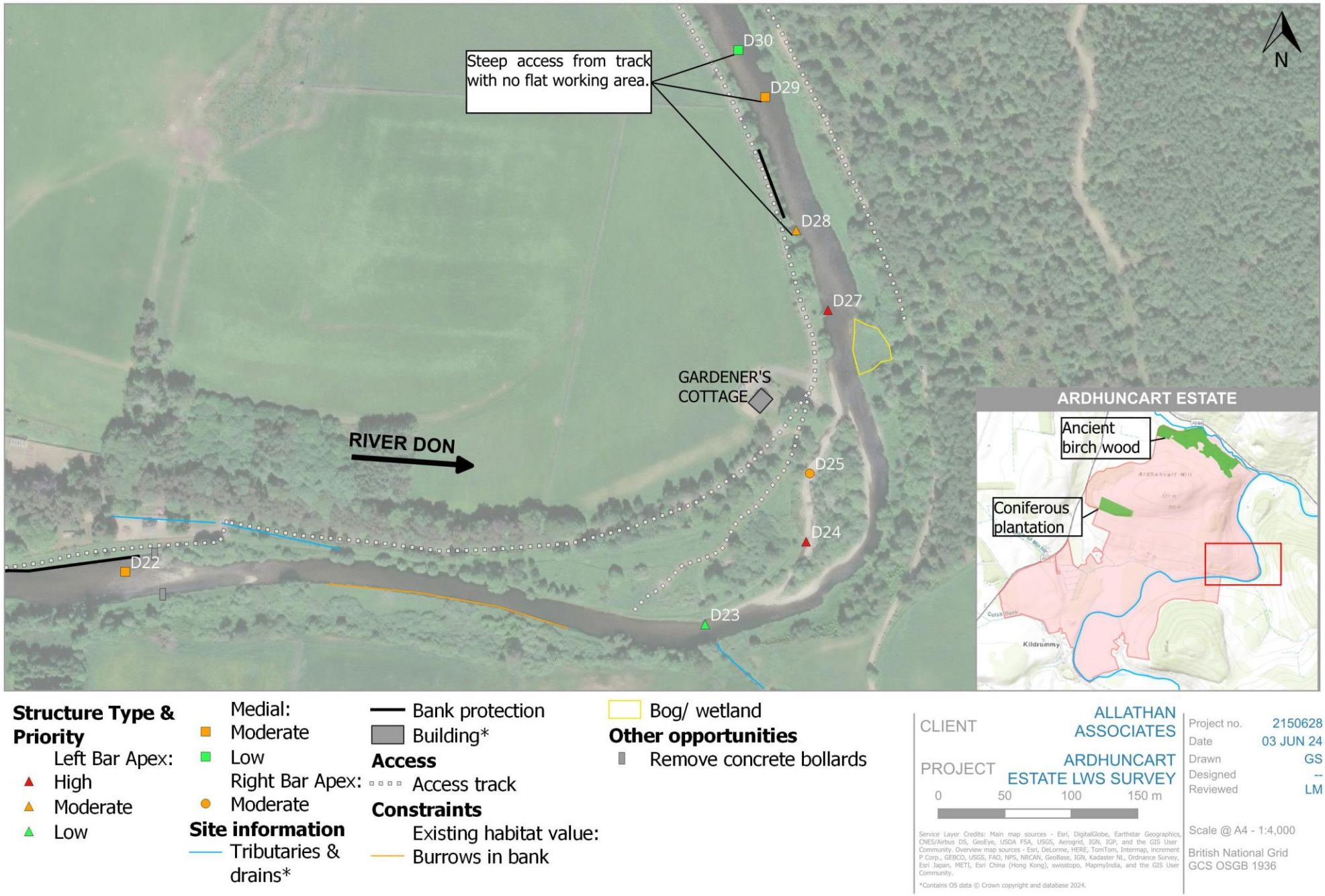


Figure 2.4 Proposed LWS locations along the River Don, Gardener's Cottage vicinity (D22 to D30).

LWS RIVER DON - STRUCTURES D30 to D39 - MAP 5 of 6

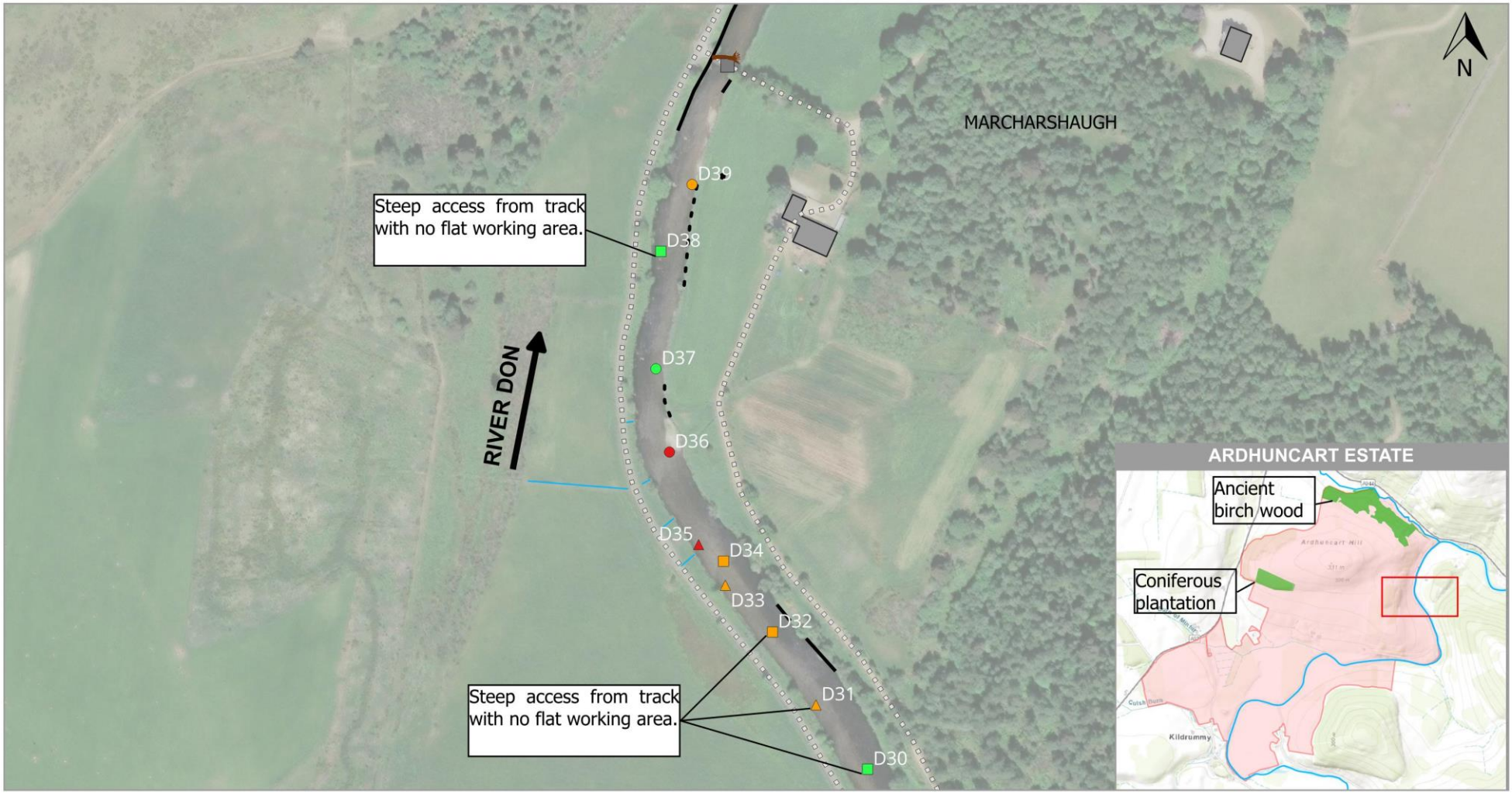


Figure 2.5 Proposed LWS locations along the River Don, Macharshaugh vicinity (D30 to D39). Note that boulders for ballast can be sourced from the removal of bank protection.

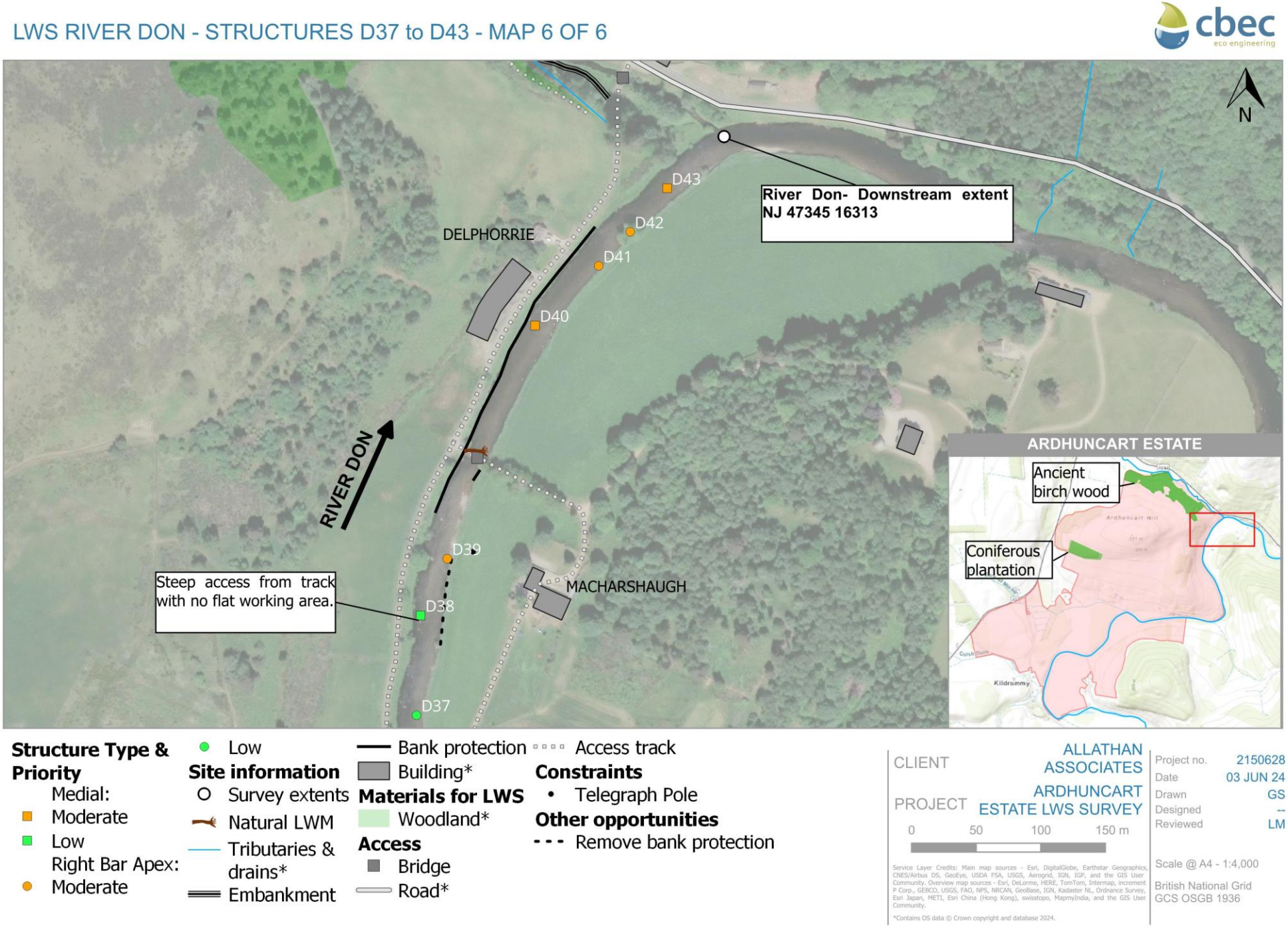


Figure 2.6 Proposed LWS locations along the River Don, Delphorrie vicinity (D37 to D43). Note that boulders for ballast can be sourced from the removal of bank protection.

2.2.2. Mossat Burn

The 0.87 km long reach of the Mossat Burn that flows through the Ardhuncart estate is a mostly straight channel with discrete sections of sinuosity; the channel is typically less than 5 m wide and set in a relatively unconfined valley. The channel exhibits a pool-riffle channel typology, but characteristic features such as channel cross-section asymmetry, alluvial bars and riffles are generally underdeveloped due to historical river management. Historical works identified during the survey include bank protection, embankments, realignment and likely dredging. The channel substrate comprises course gravel and cobbles and sand and silt, lacking an intermediate grain size fraction. The channel banks are erodible, comprising sand that provides the channel with a local and abundant supply of sand-sized sediment. Observations made during the survey indicate that coarser material (gravel) is supplied from more distal sources upstream in the catchment, with the exception of some large cobbles/ boulders that have fallen into the channel from failed bank protection. The simplified morphology of the channel has reduced the opportunity for deposition and increased the rate at which sediment is conveyed through the reach, meaning that the intermediate grain size fraction (i.e. medium and fine gravels) is transported downstream faster than the supply is replenished. Tree cover is sparse, isolated to single trees or clusters of trees along the majority of the reach; the lack of complex root structures exacerbates the already erodible nature of the banks.

Rock armour bank protection for the purpose of mitigating bank erosion and channel adjustments, in varying states of condition, is frequent along the reach. Where bank protection has prevented natural bank erosion, the channel has instead eroded the river bed and over-deepened the channel, leading to a homogeneous morphology with under-developed features. Embankments are also common along the Mossat Burn reach; the largest embankments are located at the upstream extent (NJ 48506 19001), while smaller embankments (~ 0.5 m in height) run parallel to the channel towards the middle section of the reach on the river left bank (NJ 48696 18873 to NJ 48818 18740) and are likely a product of historical dredging. Additional features pertaining to historical river management include a boulder weir (NJ 48851 18694), which likely served one of the two (now offline) lades that are present on the river right floodplain (locations centred on NJ 48605 18875 and NJ 48904 18631). The existing river conditions show that the river has self-restored natural processes to a degree where a sinuous planform has started to recover, for example in the vicinity of the failing telegraph pole located at NJ 48548 18936. Riparian vegetation is generally simple, dominated by grasses and rushes, and there is little cover over the channel to provide shade or shelter to fish.

The key benefits to be gained from LWS along the Mossat Burn reach are: improvements in river and floodplain habitat, by enhancing the development of alluvial bars and increasing morphological diversity to drive the restoration of a sinuous planform; enhancing the development of alluvial bars to increase retention of medium and fine gravels from distal sediment sources; improving the connectivity between the channel and the floodplain; and providing in-channel cover and shelter.

PLJ and LWS were considered for installation within the Mossat Burn. However, based on the walkover, LWS were deemed to offer greater benefits in terms of promoting diversity of geomorphic processes. Locations and types of LWS were determined based predominantly on their potential for geomorphic work and habitat benefits. However, potential constraints/ considerations were identified that could impact construction and/ or the potential to achieve the aims of the LWS. Extrinsic constraints (e.g. construction access) informed the prioritisation of LWS, but it is recommended

further shortlisting is carried out with closer consideration for site-specific priorities/ constraints. The constraints pertaining to the Mossat Burn reach are summarised below.

- There is a telegraph pole located ~8 m from the river left bank that could be a constraint to construction. Increased erosion to the river left bank is possible and, in time, could impact this asset. It is recommended that discussions with the asset owner are undertaken to propose that this telegraph pole is moved to the river right and set back from the channel (ideally outwith the boundary of the meander belt) when the repairs are carried out. This would mitigate the erosion risk to the telegraph pole and allow space for the meanders to develop.
- A floodplain wetland area is present on river left towards the upstream extent of the reach, located at NJ 48526 18997. Bog mats (or similar) may be required for construction access.
- The access track along the river right of the Mossat Burn is overgrown. Clearance and/ or pruning of the overgrown vegetation may be required for access to the river right floodplain.

Locations identified as appropriate for the implementation of LWS and additional opportunities for river habitat improvements within the Mossat Burn are presented in Figure 2.7 and Figure 2.8. Full details of each structure are provided in Appendix A.

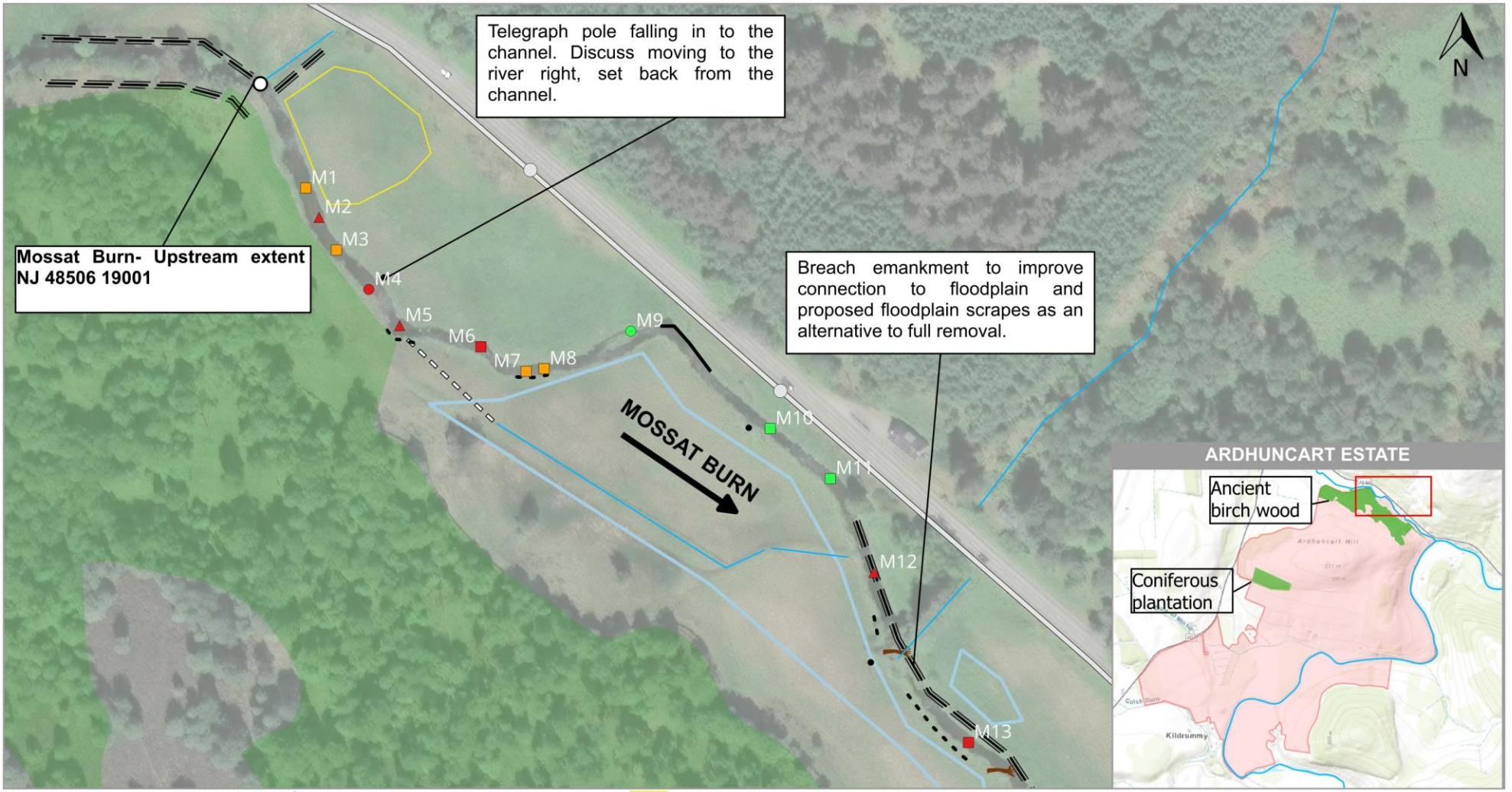


Figure 2.7 Proposed LWS locations along the Mossat Burn from the upstream survey extent to the river left tributary confluence (M1 to M13). Note that boulders for ballast can be sourced from the removal of bank protection.

LWS MOSSAT BURN - STRUCTURES M13 to M26 - MAP 2 OF 2

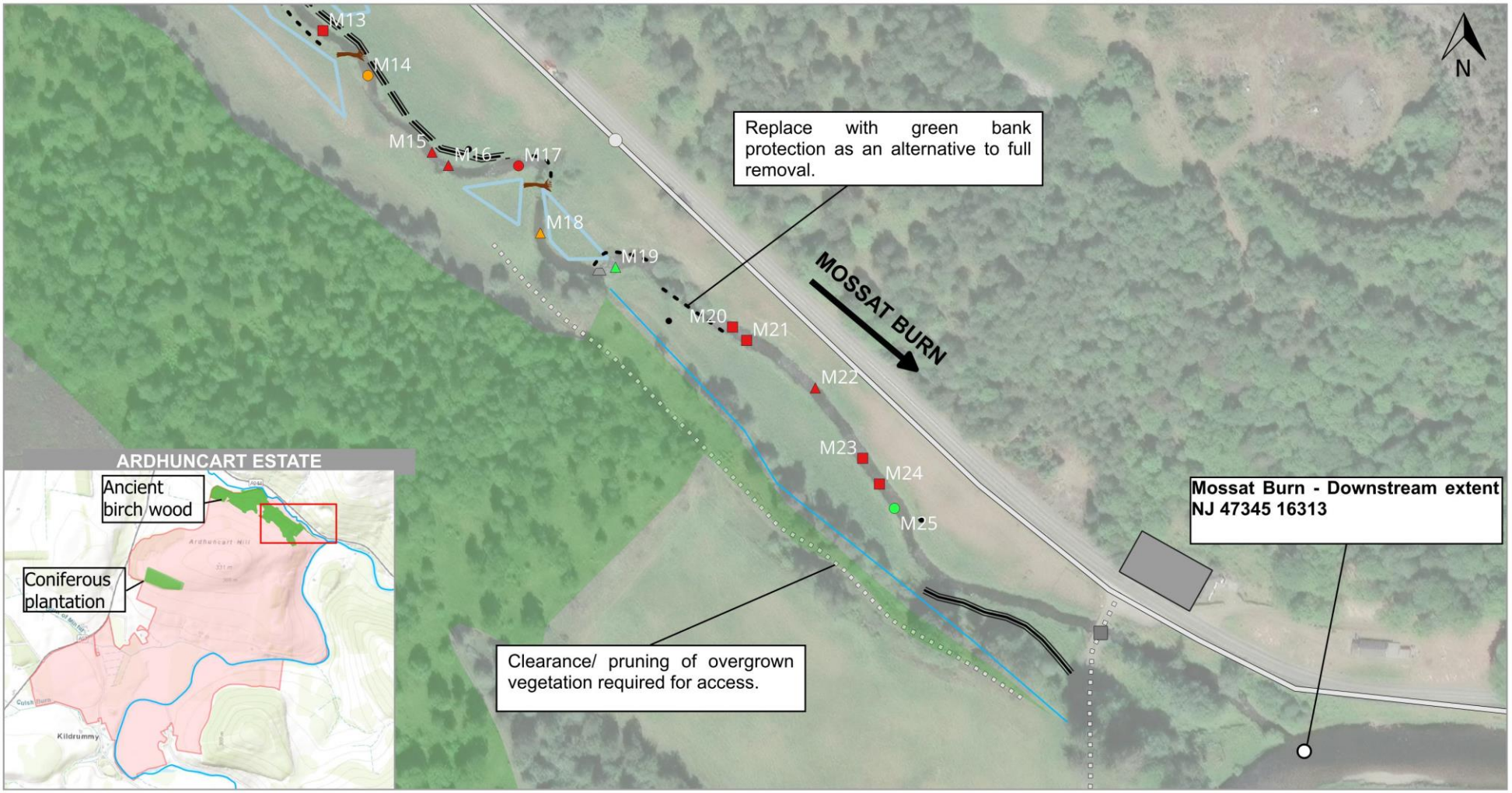


Figure 2.8 Proposed LWS locations along the Mossat Burn from the river left tributary confluence to the downstream survey extent (M13 to M26). Note that boulders for ballast can be sourced from the removal of bank protection.

3. IMPLEMENTATION

3.1 LARGE WOOD STRUCTURES

3.1.1. Sizing of Structures

To ensure the effectiveness of the LWS in improving the physical complexity and ecological condition of the channel, the geomorphic context of the wider study extent has been taken into consideration. In particular, it is important to consider the interaction between flow, channel geometry (e.g. cross-sectional shape, slope), bed particle size and the large wood itself; these interactions are important in determining how sediment is stored in the vicinity of LWS and key to enhancing physical habitat complexity (and, therefore, biodiversity). If the LWS are not suitably scaled to channel dimensions, particularly width, their influence on river processes (i.e. sediment erosion and deposition) may not be sufficient to induce the intended degree of physical and ecological enhancement to the channel.

cbec's experience has shown that, to have a tangible effect on geomorphic processes within river systems such as the Don catchment, LWS (both bar apex and medial) must be constructed using multiple trees. Assuming a trunk diameter averaging 300–600 mm, three to five trees (with root plates attached) would be required to construct a standard sized structure. This ensures that the structures are of sufficient size to provide the cross-sectional area required to influence in-channel flow hydraulics; in particular, the vertical extent of a structure above the channel bed and the width of a structure presented to the prevailing flood flow direction are important. A larger structure may be required in certain locations, for example where a high level of channel roughness is already present. These large structures are typically formed of either more or larger trees to ensure stability and influence hydraulics once installed. This is particularly relevant to the River Don reach, where either larger trees or structures comprising 6 or 7 trees are recommended, given the large cross-sectional area and depth of the channel. Structures D24 and D25 are set in a smaller channel, where the River Don splits around the island (located at NJ 49091 17454) directly upstream of Gardeners Cottage; accordingly, a standard sized structure comprising three to five trees would be appropriate here. LWS are considered feasible for installation where the depth is less than ~0.75 m under normal flow conditions. Depth was not accurately measured as part of the survey, but medial LWS were proposed where morphological characteristics indicated shallow sections of channel (e.g. protruding boulders or disruption to surface flow). Where depth exceeds ~0.75 m at proposed medial LWS locations, these structures should be descoped.

In addition to diameter, the structure length should be scaled according to the cross-sectional size of the watercourse to ensure the effectiveness and stability of the LWS. Bankfull channel width is relatively consistent along the River Don and Mossat Burn reaches, averaging widths of 22 m and 4 m, respectively. Therefore, structure length requirements will require little 'fine tuning' from the standardised trunk length for each LWS location (shown below in Table 3.1). Shorter trunk lengths are required for structures D24 and D25 along the River Don as these structures are set in a narrower channel (~9 m wide) where the River Don splits around the island. Here, trunk lengths should measure ~6 m to allow for the structure to be sufficiently buried into the bed/ bank with enough remaining length to interact with flow (see below). Accordingly, it is recommended that some flexibility be adopted and judgement be applied regarding the number and size of trees required for each structure.

Where bar apex structures have been proposed along the Mossat Burn reach, these should extend approximately one quarter to one third of the way into the active channel. Where bar apex structures have been proposed along the River Don reach, these should extend up to just one quarter of the way into the active channel, given its larger width and to mitigate abrupt changes to sinuosity. The remaining ~40–50% of the trunk length is to be buried into the bank. For the River Don and Mossat Burn, minimum trunk lengths (including root plate) of ~15 m and ~3 m are recommended, respectively; this would allow the LWS (composed of overlapping individual wood pieces) to extend into the channel to a sufficient extent while retaining 40–50% of the trunk length to be incorporated into the channel bank to stabilise the structure. Medial structures are also scaled according to channel width, although these structures are stabilised by burying a proportion of the trunk into the channel bed, as opposed to the bank (i.e. as for bar apex structures). A summary of the average channel widths for each site and the recommended trunk lengths have been provided within Table 3.1, to be used as a guide for sourcing the material and applying for funding. Exact quantities required will be dependent on how structures are shortlisted for installation by the Ardhuncart Estate and the size of available trees.

Table 3.1 Recommendations for sourcing structure materials.

Reach	Average Channel Width (m)	Large Wood Structure Requirements			
		Trunk Length* (m)	Length Buried in Bank/ Bed (m)	Number of Trees per Structure	Total Number of Structures
River Don**	22	11	6	6 or 7	43
Mossat Burn	4	4	2	3 of 4	25

*If such trunk lengths unavailable, lateral extent into channel to be achieved through overlapping wood pieces

** Shorter trunk lengths and fewer trees are required for structures D24 and D25 along the River Don as these structures are set in a narrower channel (~9 m wide). Here, trunk lengths should measure ~6 m and comprise 3 to 5 trees (see above).

It is acknowledged that trunks over 10 m in length can be difficult to source and/ or transport, particularly in the quantities required for the large structures proposed for the purposes of enhancing geomorphic processes on the River Don. If longer trunks are unavailable, a composite structure consisting of overlapping shorter lengths (e.g. ~8 m long) could be constructed. For a bar apex LWS built as a composite structure, the first set of shorter lengths (i.e. 4–5 trunks for a large structure) would be anchored in the bank; then, working into the channel, the next set of trunks would be installed overlapping the previous set. In this way the structure would be extended into the channel to the required length. If material sourcing dictates that composite structures will be required, it is recommended that as part of construction supervision, a member of cbec's geomorphology team ensures the stability of these features once installed.

cbec has produced indicative design illustrations for both bar apex and medial structures, intended to guide the implementation of the LWS; these are provided in Appendix B. To date, cbec has installed over two hundred large wood structures according to these specifications; none of these structures

has been transported downstream from their site of implementation, with only localised adjustments observed in a very few examples. Accordingly, in our experience, if the structures are implemented according to the instructions provided, the risk of these structures mobilising and being transported downstream to cause damage elsewhere is considered to be very low.

3.1.2. Wood & Ballast for Structures

Where possible, it is recommended that trees for LWS are sourced on or close to the site to minimise construction costs. Recently wind-felled trees are the preferred source material, increasing the sustainability of the construction phase and reducing the cost associated with felling the wood. If suitable wind-felled trees are unavailable, it is recommended that a selection of living trees from a local plantation are felled (with root plates retained) as a source of material for the LWS. As a general rule, a tree measuring an average diameter of between 300 mm and 600 mm at the base of its trunk will be associated with a root plate of sufficient size to be suitable for a LWS. Woodland sites have been identified within the Ardhuncart estate that are a potential source of trees for LWS. The birch woodland located on the southwestern valley side of the Mossat Burn (centred on NJ 48588 18782) and the coniferous plantation located on the southwestern side of Ardhuncart Hill (centred on NJ 47536 18142) both present potential sources of wind-felled trees. However, it is recommended that the coniferous plantation is used as a source of material to prevent damage to the birch woodland (including deadwood habitat from wind-felled trees), which is protected by ancient woodland status.

When constructed, the root plates in a LWS will face upstream into the flow. Therefore, the complexity of the root network is of paramount importance to the effectiveness of the structure at influencing hydraulic and therefore geomorphic processes. At each stage of the construction process (tree felling, transportation of the wood to the installation location and installing the structure), parts of the root plate are lost. As a result, it is essential that as much of the root plate as possible remains intact during the felling process. To maximise the size of the root plate that remains intact when it is extracted from the ground, it is recommended that the following steps are followed.

- Loosen the ground ~1–2 m away from the base of the trunk, around the full circumference of the tree, using an excavator bucket. This enables the root to be freed from the ground more easily and increases the extent of the root structure that will remain attached, compared with if the tree was pulled straight from the ground.
- While still in-situ, move the tree from side to side, using a timber grab attachment instead of the excavator bucket, to loosen the roots from the soil and pull the tree out of the ground.
- Load felled trees into a tracked dumper to move to a storage location, or ideally to the proposed installation locations to reduce the number of times the material needs to be handled by machinery.

The recommended length of tree trunk for each structure is dependent on the width of the channel at the proposed installation location. Appropriate sizing of these structures for the two study sites has been outlined in the previous section (3.1.1). However, in some cases where the full tree length is not required, the tree may be 'capped' to an appropriate length before it is felled. The capped sections could be left as deadwood habitat within the plantation or incorporated within the LWS.

In order to provide additional confidence in the stability of LWS, ballast in the form of large alluvial boulders is used to secure the individual trees in place, counteracting the buoyancy of the wood. Ideally, these should be sourced locally from the river channel in the vicinity of the specific LWS. There are a number of locations identified where appropriate boulders for this purpose have been used to artificially influence river processes (e.g. protect riverbanks, for flow deflection); these provide preferential sources for ballast material (since their current configuration presents an impact/ engineering pressure to natural river condition). Areas where boulders suitable for ballast were identified along the River Don and Mossat Burn in sections of bank protection are optioned for

removal in this report. These are presented in Figure 2.2, Figure 2.5, Figure 2.6, Figure 2.7 and Figure 2.8. However, the quantity of material required for the construction phase has not been considered here, due to this being largely dependent on the number of structures that Ardhuncart Estate wishes to shortlist for implementation through the study reach.

4. ADDITIONAL OPPORTUNITIES

In addition to identification of potential LWS locations, this project has identified further opportunities that could be undertaken in conjunction with the installation of LWS, thus offering further improvements to river and floodplain habitats across the Estate. These include the following.

- Removal of disused or failed bank protection along sections of the River Don and Mossat Burn could be undertaken to support the recovery of a dynamic sinuous planform. Locations are proposed where increased sinuosity could potentially be accommodated within the constraints of land use, infrastructure and assets.
- Removal or systematic breaching of embankments could be undertaken along sections of the Mossat Burn to improve connectivity between the channel and floodplain. Locations are proposed where more frequent inundation of the floodplain could likely be accommodated given modern land use.
- Low-intervention restoration could be undertaken for the area of the floodplain that has recently reconnected to the channel as a result of the breached embankment at Jock's Pool. Some natural floodplain processes and features have already recovered here, including periodic flooding, sediment deposition, LWM deposition and the formation of a pond within a paleochannel. Low-intervention restoration options include:
    - riparian planting of the floodplain to improve riparian habitat and climate resilience (diverse riparian vegetation helps slow the flow of water across the floodplain, increase infiltration, improve water quality and provide shade and shelter for in-channel species);
    - wetland planting around the margins of the existing wetland pond to enhance this habitat;
    - further embankment breaching to provide downstream connection to the channel where flood flows could renter the channel (also potential to connect flood flows to the Auld Water that flows along the northern boundary of the floodplain).

Removal of the boulder weir was considered as an additional option for improving habitat but was deprioritised as this barrier is small and likely passable to salmon and trout species. Removing the structure poses a risk of head cut processes upstream (erosion to the bed that propagates in an upstream direction), which would negatively impact efforts to reconnect the channel to the floodplain and destabilise installed LWS. Therefore, it is recommended that this structure is left in situ.

APPENDIX A

LARGE WOOD STRUCTURE TABLE

1. OVERVIEW

The following table provides a comprehensive breakdown of the large wood structures (LWS) proposed within the Ardhuncart Estate within the following reaches:

1. River Don (D),
2. Mossat Burn (M).

This appendix builds on the summary provided in Section 2 of the 'Hydrogeomorphic assessment and design recommendations for large wood structures' report (cbec [Draft], 2024), and should be read as a supporting document to this main report.

All locations presenting potential for improving ecological and geomorphic condition within the surveyed areas of the Ardhuncart Estate were mapped during the survey and prioritised accordingly, to provide a comprehensive overview of the LWS potential within the catchment. It is understood that implementation may be dictated by the availability of funding, suitable materials (i.e. number and size of wind-felled trees available), safe machinery access and ecological or archaeological constraints (i.e. avoiding disturbance to prime Atlantic Salmon spawning locations). A combination of these factors may result in certain reaches being prioritised for implementation over other sections. Therefore, it is hoped that the sixty-eight structure locations identified within this report will provide the project group with some flexibility in achieving their implementation target.

Table 1.1 Quantity and prioritisation of LWS across the three study areas.

Site	Surveyed (Priority Level)			
	High	Moderate	Low	Total
River Don	13	21	9	43
Mossat Burn	14	6	5	25
				68

Where bar apex structures are proposed, these features are designed to promote the development of an asymmetrical cross-section, promoting the accumulation of sediment along the insides of meander bends and scour/ erosion along the outsides of bends. These features encourage further development of meanders, increasing the sinuosity of the watercourse by promoting lateral channel migration across the floodplain. Therefore, bank erosion can be expected to increase opposite these structures as part of this natural process of channel adjustment. Whilst erosion is a natural geomorphic process, it is acknowledged that it can be undesirable if infrastructure is located in close proximity to the watercourse (<30 m).

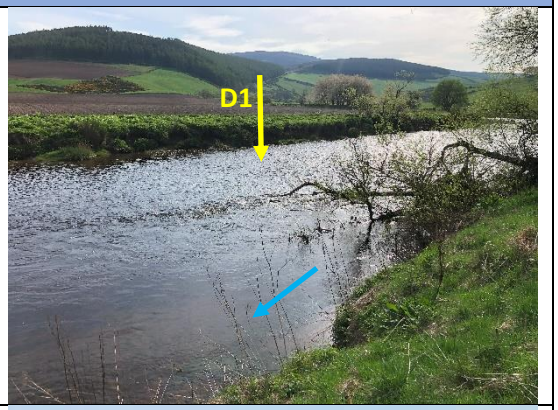
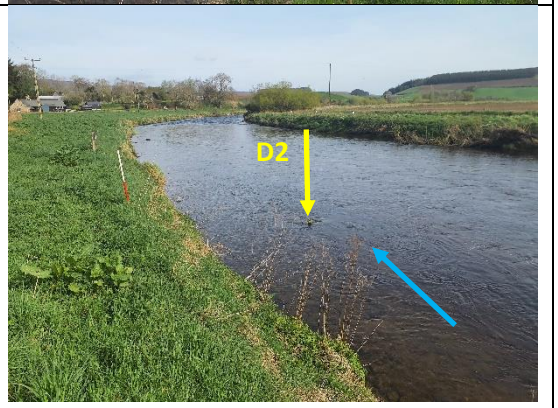
Along the Mossat Burn, the bank protection in the bank opposite proposed LWS M5, M17 and M19 should be removed to allow the necessary erosion that facilitates the development of meanders and increased sinuosity. There is a telegraph pole opposite the location of LWS M4 that is failing due to river bank erosion; it is recommended that discussions with the asset owner are undertaken to propose that this telegraph pole is moved to the river right and set back from the channel (ideally outwith the boundary of the meander belt) when the repairs are carried out. This would mitigate the erosion risk to the telegraph pole and allow space for the meanders to develop.

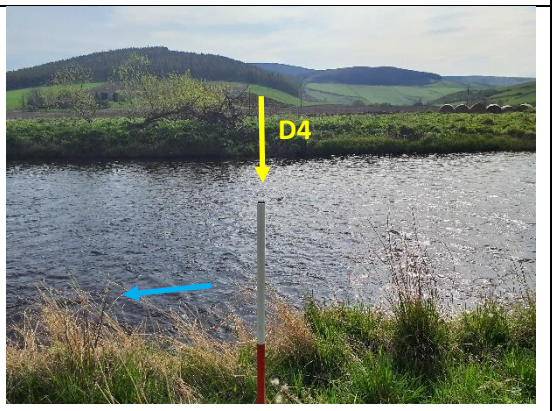
Medial structures encourage the accumulation of bar forms in the centre of the channel, promoting the bifurcation of flow and thereby diversifying morphology. These features can encourage localised widening of the channel but are considerably less likely to encourage migration of the channel

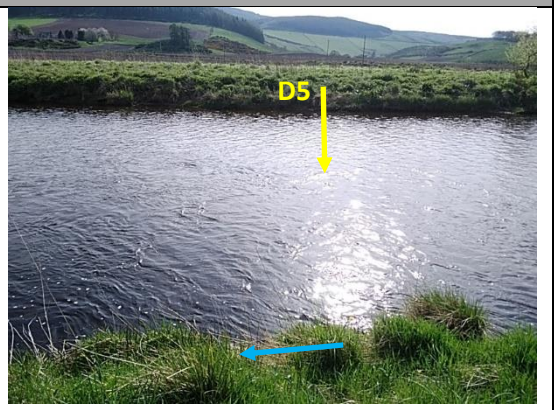
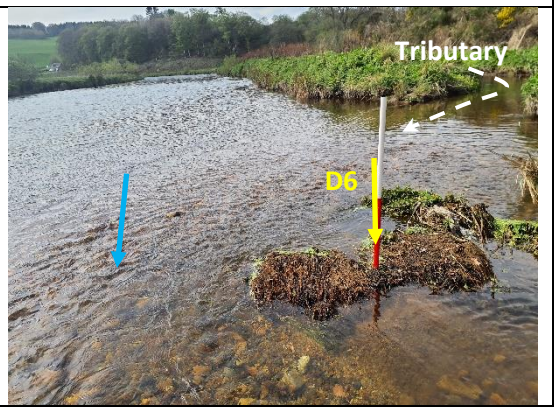
planform than the apex structures. Along most of the River Don reach, the channel is too deep for the installation of medial structures (>0.75 m); furthermore, the size of structures (scaled to the size of the channel) required to effectively impact in-channel processes is too large to be considered feasible. Therefore, bar apex structures have been proposed where medial structures are not feasible.

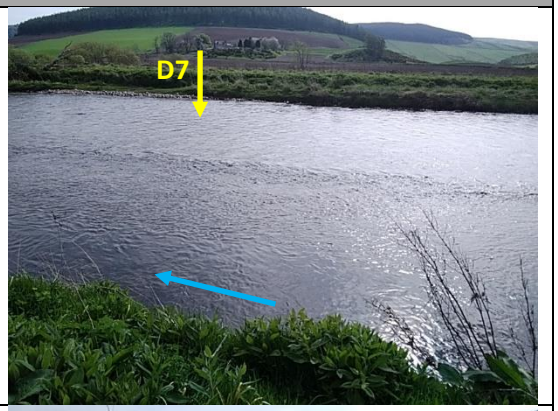
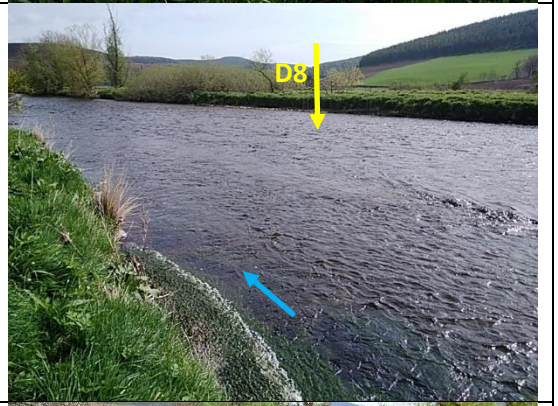
Access constraints were identified along the Mossat Burn and River Don. Along the River Don, there is a steep gradient and limited flat working area between the river banks and access track, which could impact the construction of LWS D28 to 32 and D38. There may be potential to overcome these constraints with the use of long reach machinery. Furthermore, bog/ wetland areas are present along the Mossat Burn and River Don. Bog mats (or similar) maybe required for access to the locations of LWS M1 and D26.

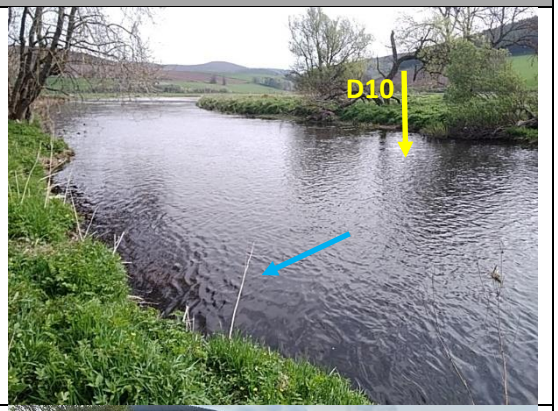
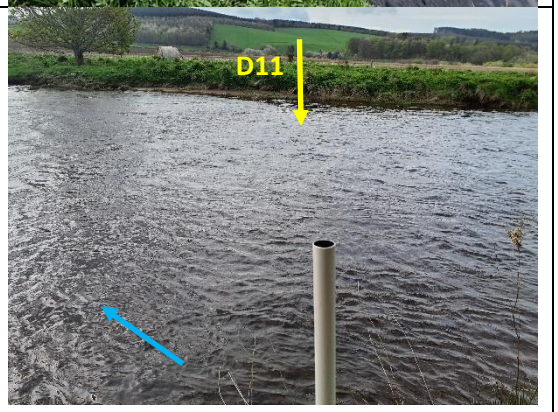
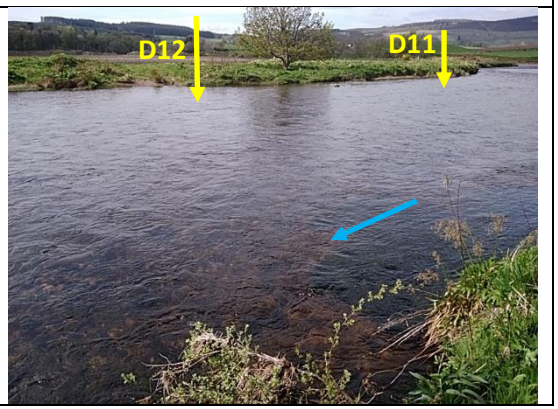
2. RIVER DON (D)

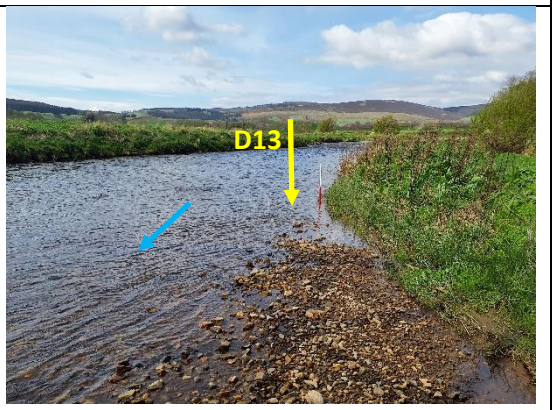
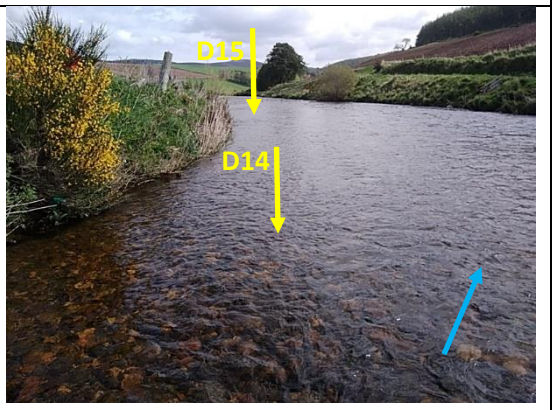
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
River Don						
D1	347218	816359	Right Bar Apex	Low	Positioned to encourage development of proto bar on river right bank. Wide and homogeneous section of channel with potential for enhancing morphological diversity and adding in-channel cover.	
D2	347172	816390	Medial	Low	Wide and homogeneous section of channel with area of localised deposition present towards river left bank; structure could enhance these processes and encourage flow diversity. Telegraph pole located ~8 m from river left bank could be a constraint to construction. Increased erosion to the river left bank is possible and, in time, could impact this asset.	

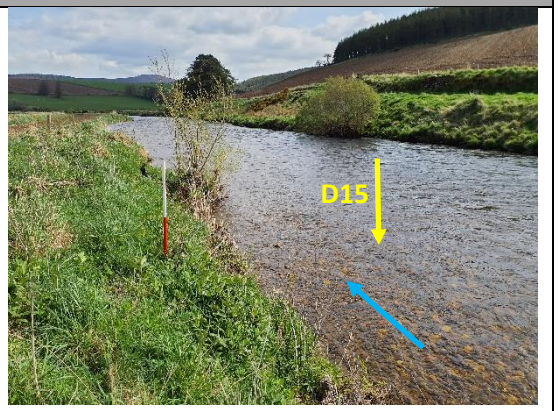
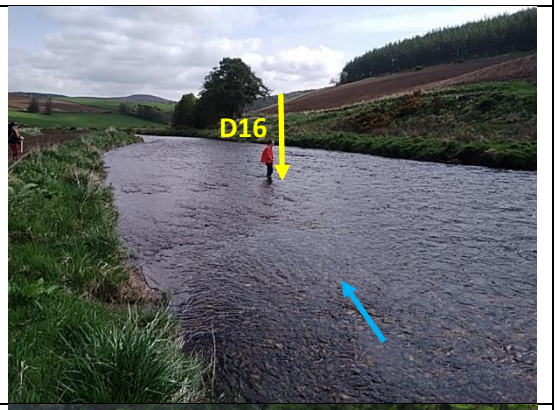
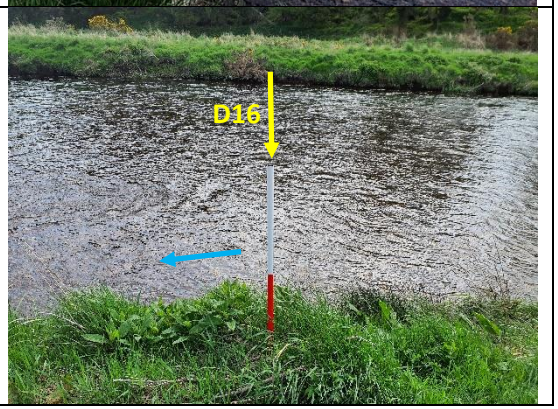
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D3	347163	816430	Right bar apex	High	Proto bar present on river right bank. Position upstream of river right bank telegraph pole at the upstream extent of the proto bar to encourage development of proto bar. Encourage sediment storage, diversifying the in-channel habitat and increasing channel complexity.	
D4	347136	816569	Right bar apex	Low	Wide and homogeneous channel morphology. Positioned to encourage deposition on the river right bank, thus encouraging flow to the river left where sediment is readily available in the existing eroding bank. The increased sediment supply supports the development of depositional features around LWS. Existing eroding bank is ~34 m away from a farm building's boundary fence, which is not considered to be at imminent risk of bank erosion. However, this LWS would likely accelerate erosion in the first instance, with little certainty as to where this bank would stabilise in future. Bank protection measures may be required in the future.	

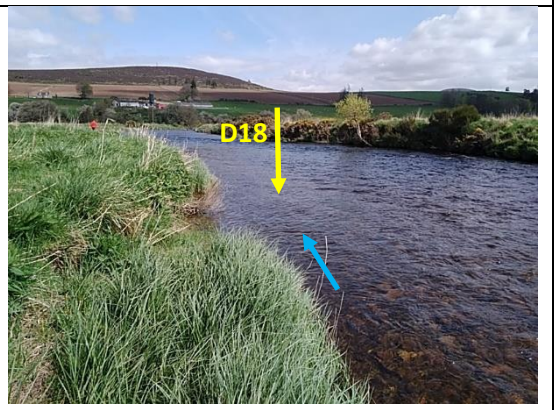
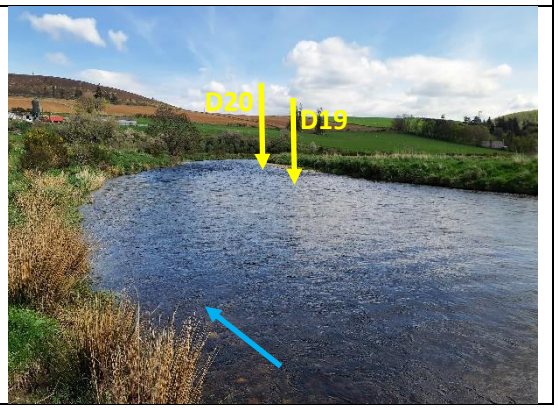
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D5	347139	816618	Medial	Low	Wide and homogeneous section of channel. LWS proposed to capture sediment supply from nearby bank erosion with the view to encourage morphological diversity and benefit habitat by providing in-channel cover. Positioned in the centre of the channel, opposite the boulder in the river left bank. Depth is unknown; if the channel is deeper than 0.75 m then this LWS should be descoped.	
D6	347151	816706	Left Bar Apex	High	Proto bar present on river left bank. Positioned on the grass tussock (see photo) to encourage development of proto bar. LWS aims to capture and store sediment supply from the nearby tributary.	

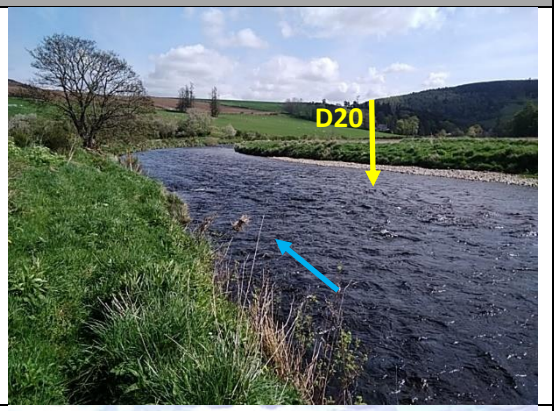
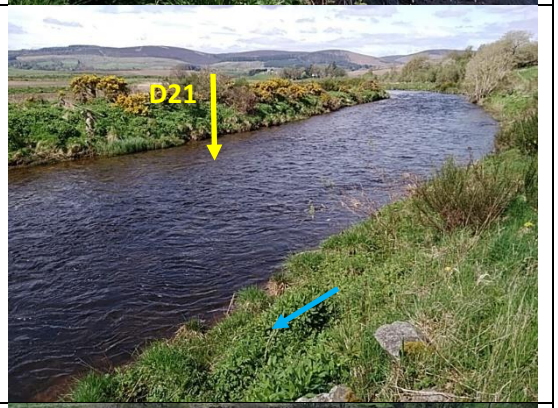
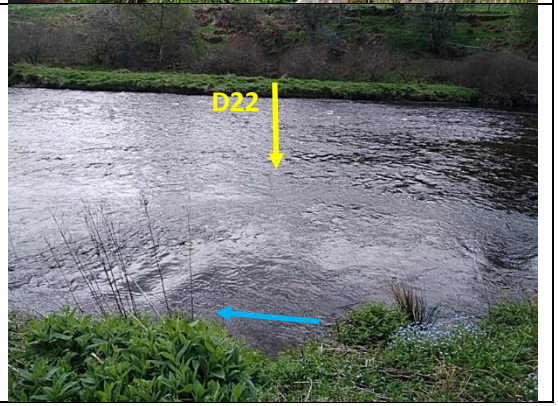
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D7	347179	816734	Right Bar Apex	Moderate	Wide homogeneous channel morphology. LWS positioned to encourage development of proto bar on river right bank. Paired with downstream LWS D8.	
D8	347200	816794	Right Bar Apex	Moderate	Wide homogeneous channel morphology. LWS positioned to encourage development of proto bar on river right bank. Paired with upstream LWS D7.	
D9	347205	816854	Left Bar Apex	Low	Wide homogeneous channel morphology. LWS positioned to encourage development of proto bar on river left bank. Low priority due to potential access constraints posed by steep banks.	

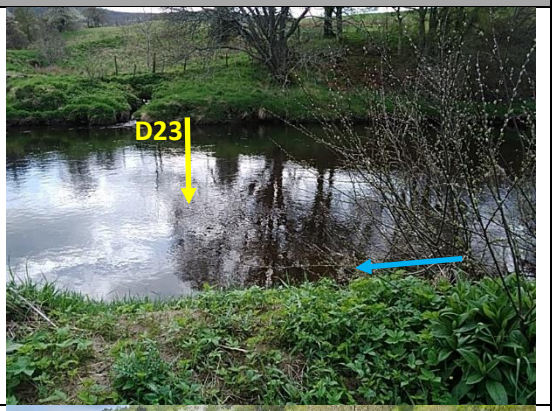
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D10	347253	816943	Right Bar Apex	High	Wide homogeneous channel morphology. LWS positioned to encourage development of proto bar on river right bank. LWS aims to extend roughness out into the channel next to existing willow in the river right bank and enhance deposition of fine sediment.	
D11	347458	817012	Right Bar Apex	High	Wide homogeneous channel morphology. LWS positioned to encourage development of proto bar on river right bank and provide habitat benefit (i.e. in-channel cover). LWS aims to capture sediment supplied from the nearby upstream bank erosion. Paired with downstream LWS D12.	
D12	347490	817000	Right Bar Apex	Moderate	Wide homogeneous channel morphology. LWS positioned to encourage development of proto bar on river right bank and provide habitat benefit (i.e. in-channel cover). LWS aims to capture sediment supplied from the nearby upstream bank erosion.	

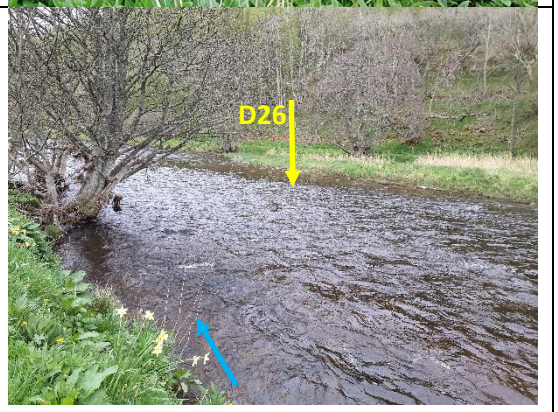
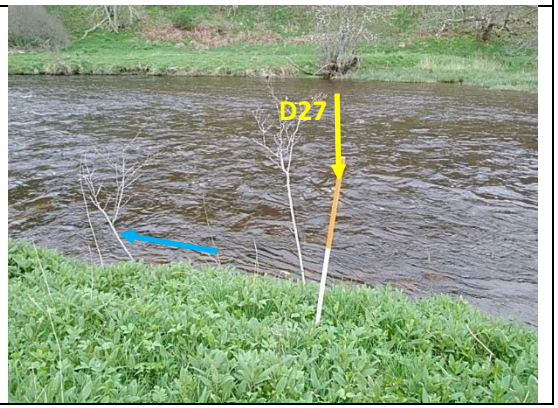
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
					Paired with upstream LWS D11.	
D13	347601	816985	Left Bar Apex	High	Proto bar present on river left bank, that extends around the meander bend, passing under the bridge. LWS positioned to encourage development of the proto bar. LWS aims to capture sediment supplied from the nearby upstream bank erosion. There is sufficient capacity under the span of the bridge to accommodate the development of this bar.	
D14	347656	816998	Left Bar Apex	Moderate	Proto bar present on river left bank that extends around the meander bed. LWS positioned to between the broom bush and wooden post (see photograph) to encourage development of the proto bar. LWS positioned in an area where favourable spawning habitat is present. Further consideration is recommended regarding the impact on the site-wide presence of spawning habitat.	

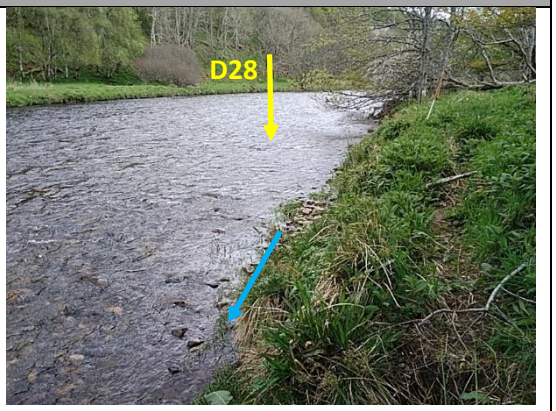
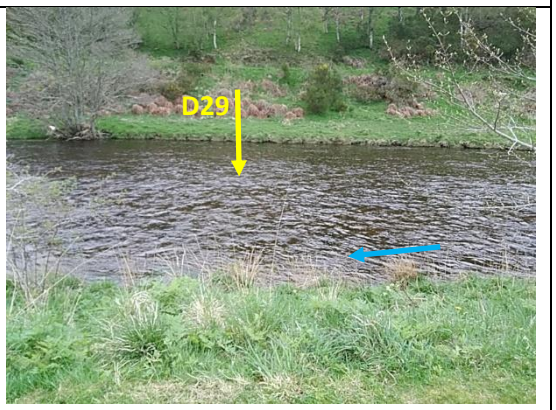
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D15	347679	817015	Left Bar Apex	High	Proto bar present on river left bank that extends around the meander bed. LWS positioned to encourage development of the proto bar. LWS positioned in an area where favourable spawning habitat is present. Further consideration is recommended regarding the impact on the site-wide presence of spawning habitat.	
D16	347736	817061	Medial	Moderate	Wider section with potential to add diversity and improve in-channel cover. LWS positioned in an area where favourable spawning habitat is present. Further consideration is recommended regarding the impact on the site-wide presence of spawning habitat.	
D17	347822	817152	Medial	Moderate	Wide homogeneous channel morphology. Potential to add diversity and improve in-channel cover. LWS positioned in an area where favourable spawning habitat is present. Further consideration is recommended regarding the impact	

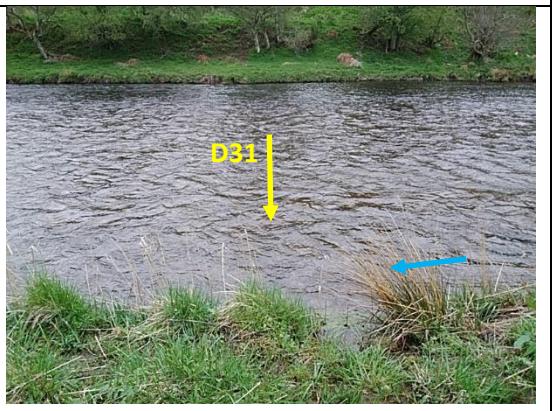
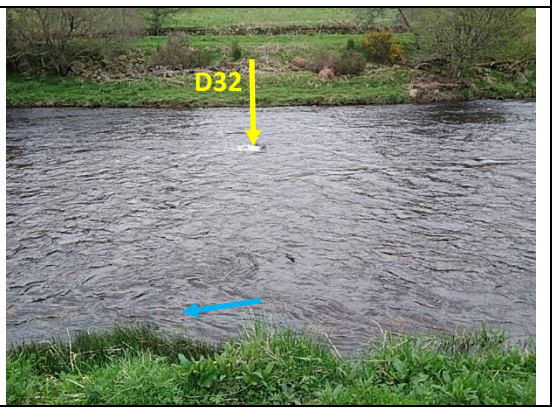
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
					on the site-wide presence of spawning habitat.	
D18	347837	817191	Left Bar Apex	Moderate	Proto bar present on river left bank. LWS positioned to encourage development of the proto bar to enhance in-channel diversity. LWS positioned in an area where favourable spawning habitat is present. Further consideration is recommended regarding the impact on the site-wide presence of spawning habitat.	
D19	347890	817348	Right Bar Apex	High	Under-developed point bar present on river left bank. No tree cover on adjacent banks. LWS positioned at the upstream extent of the bar to encourage bar development and benefit habitat (i.e. in-channel cover). Paired with downstream LWS D20.	

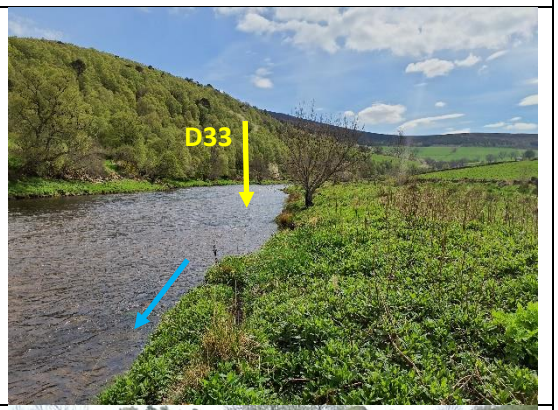
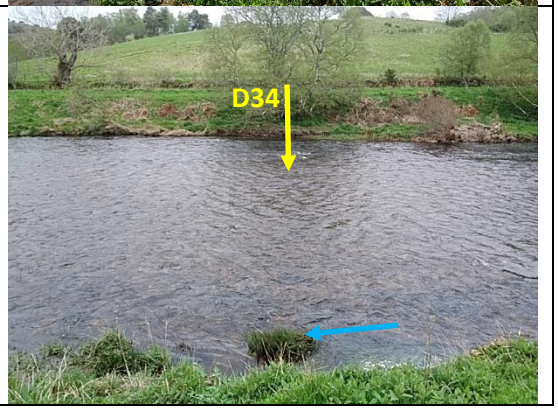
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D20	347904	817375	Right Bar Apex	High	Under-developed point bar present on river left bank. LWS positioned at the upstream extent of the bar to encourage bar development and benefit habitat (i.e. in-channel cover). Paired with upstream LWS D19.	
D21	348132	817410	Right Bar Apex	Moderate	Homogeneous channel morphology with area of localised deposition present on river right bank. LWS positioned to enhance deposition on the river right bank and increase morphological diversity.	
D22	348561	817404	Medial	Moderate	Medial proto bar present in a wide section of the channel. LWS positioned ~20 m upstream of the vegetated bar to encourage upstream development of the bar.	

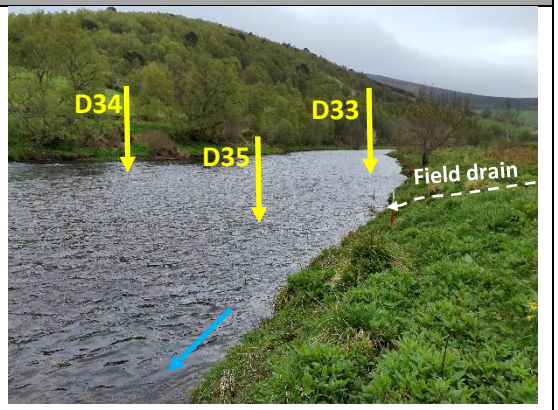
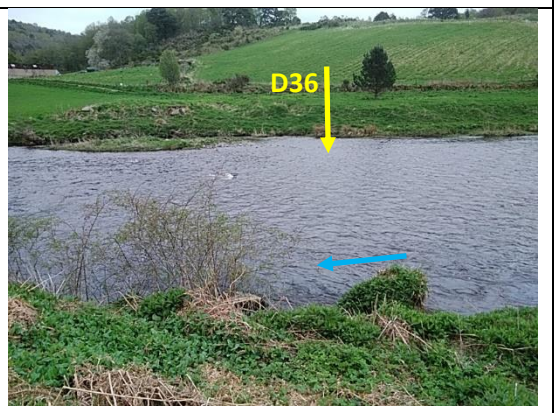
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D23	348997	817364	Left Bar Apex	Low	Proto bar present on the river left bank. Deposition of fine sediment coating proto bar substrate. LWS positioned to encourage development of the bar and benefit habitat (i.e. in-channel cover).	
D24	349073	817426	Left Bar Apex	High	Proto bar present on the river left bank. LWS positioned to encourage development of the bar and increase in-channel diversity. Deflection of flow to river right bank would enhance localised erosion and subsequent sediment supply, which supports the formation of bars. Additional benefit to habitat (i.e. in-channel cover).	

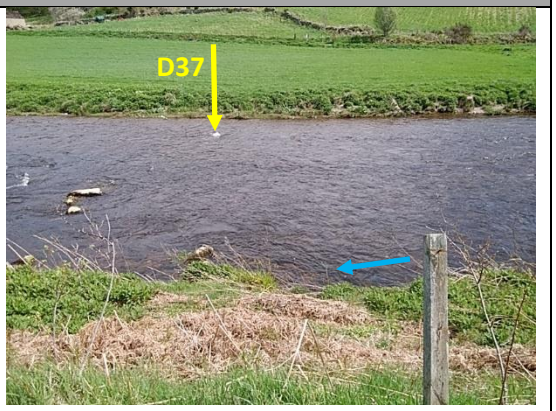
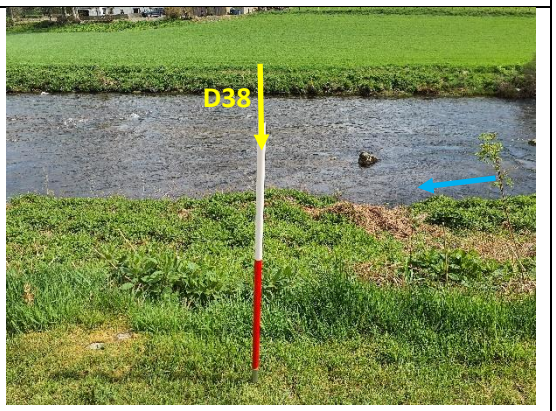
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D25	349076	817478	Medial	Moderate	Medial proto bar present in channel. LWS positioned in the centre of the channel, directly upstream of the section of turbid flow to encourage development of the proto bar.	
D26	349105	817578	Right Bar apex	Low	Homogeneous channel morphology with localised deposition of a proto bar on the river right bank. LWS positioned to encourage development of the proto bar and enhance connection to marginal wetland. Potential access constraints related to the steep gradient from the access track and marginal wetland. Bog matting may be required.	
D27	349090	817601	Left Bar Apex	High	Wide and homogeneous channel morphology. LWS positioned to encourage deposition to enhance channel diversity and provide habitat benefits (i.e. in-channel cover). Potential access constraint related to the steep gradient from the access track.	

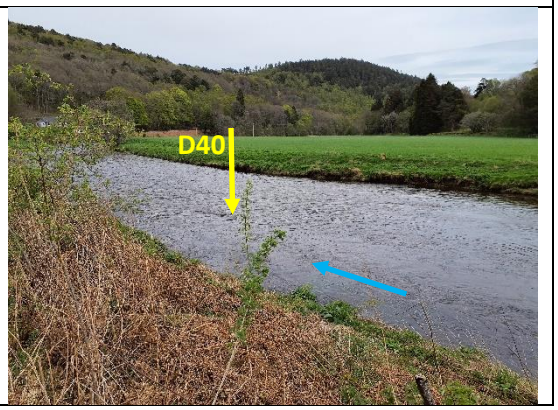
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D28	349066	817661	Left Bar Apex	Moderate	Wide and homogeneous channel morphology with localised deposition of a proto bar on the river left bank. LWS positioned to encourage development of the proto bar and provide habitat benefits (i.e. in-channel cover). Potential access constraint related to the steep gradient from the access track.	
D29	349042	817761	Medial	Moderate	Wide and homogeneous channel morphology. LWS positioned towards river right within the wider section of the channel, upstream of the of tree on the river right (see photo). LWS aims to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover). Potential access constraint related to the steep gradient from the access track.	

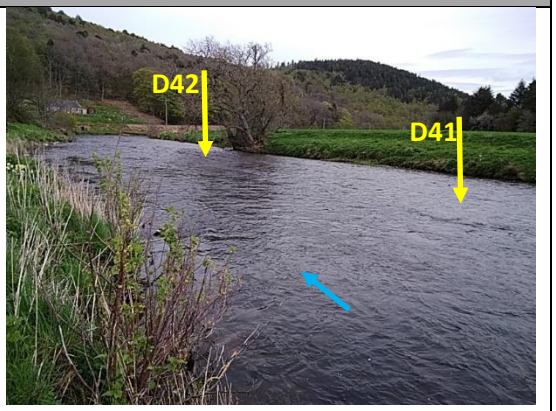
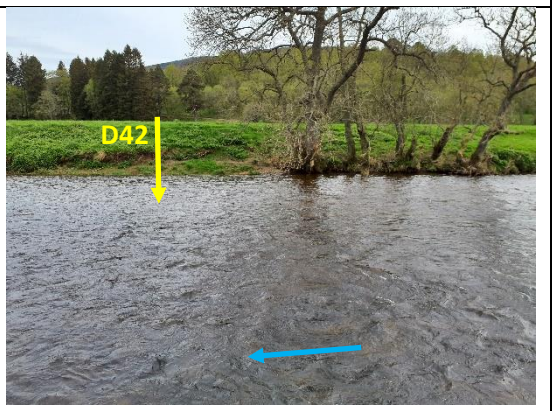
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D30	349022	817796	Medial	Low	Wide and homogeneous channel morphology. LWS positioned river right of centre on the small standing wave form to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover). Potential access constraint related to the steep gradient from the access track.	
D31	348988	817839	Left Bar Apex	Moderate	Proto bar present on the river left bank. LWS positioned to encourage development of the bar and increase in-channel diversity. Additional benefit to habitat (i.e. in-channel cover). Potential access constraint related to the steep gradient from the access track.	
D32	348959	817887	Medial	Moderate	Wide and homogeneous channel morphology. LWS position centred on the point of white water (see photo) to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover).	

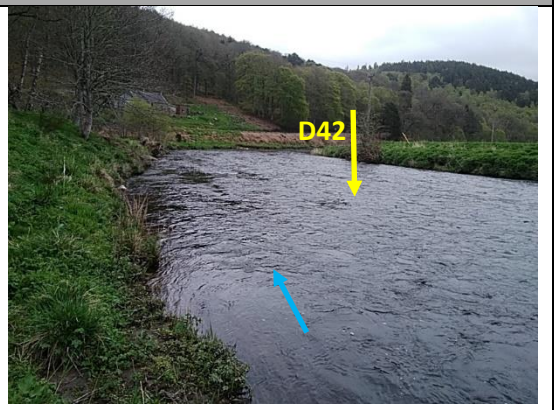
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
					Potential access constraint related to the steep gradient from the access track.	
D33	348928	817917	Left Bar Apex	Moderate	Wide and homogeneous channel morphology. LWS positioned adjacent to the tree on the river left bank (see photo) to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover).	
D34	348927	817933	Medial	Moderate	Wide and homogeneous channel morphology. LWS positioned to the river right of centre in the channel, adjacent to the tree on the river right bank (see photo). LWS aims to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover).	

Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D35	348911	817944	Left Bar Apex	High	Wide and homogeneous channel morphology with localised deposition of a proto bar on the river left bank. LWS positioned directly downstream of the nearby field drain (see photo) to enhance the development of the proto bar and provide habitat benefit (i.e. in-channel cover).	
D36	348892	818005	Right Bar Apex	High	Alluvial bar form relatively well developed compared to elsewhere in reach, but potential for in-channel habitat improvements. LWS positioned at the upstream extent of the bar to encourage bar development and complexity, providing habitat benefit (i.e. in-channel cover). Potential constraint related to different land ownership.	

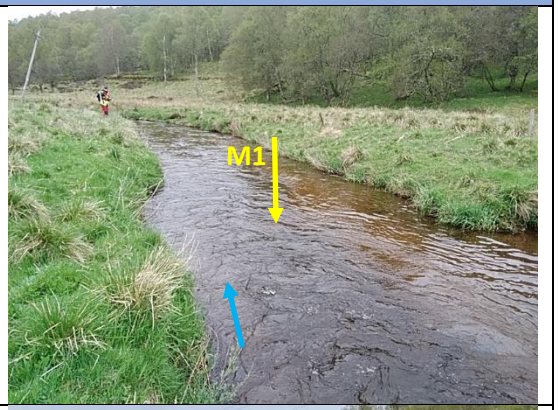
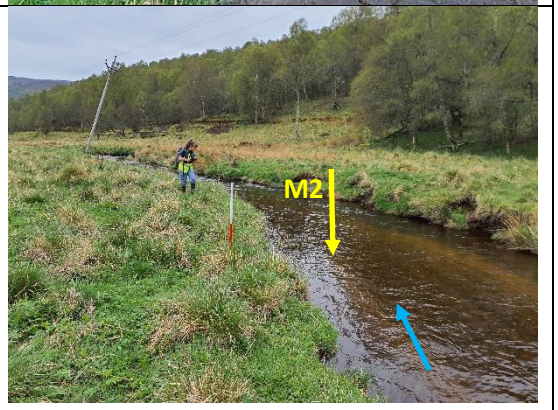
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D37	348883	818060	Right Bar Apex	Low	Relatively homogeneous channel morphology with localised deposition of a proto bar on the river left bank. LWS positioned on the small point of white water (see photo) to enhance the development of the proto bar and provide habitat benefit (i.e. in-channel cover). Potential constraint related to different land ownership.	
D38	348886	818137	Medial	Low	Wide and homogeneous channel morphology. LWS positioned toward the river left of centre in the channel, downstream of the protruding boulder (see photo) to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover). Low priority as there is existing channel roughness provided by boulders in the vicinity, however the addition of LWS would provide habitat benefit and encourage deposition of gravels.	

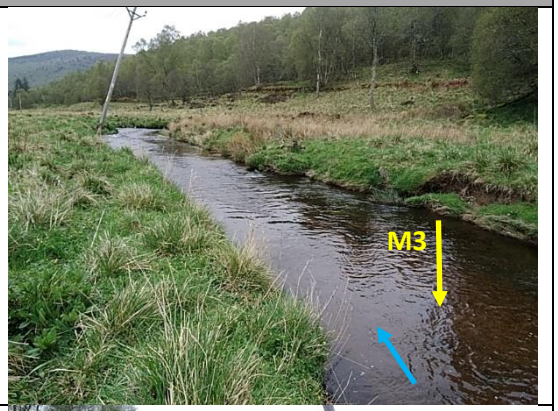
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D39	348907	818181	Right Bar Apex **or** Medial	Moderate	Wide and homogeneous channel morphology with localised deposition of a proto bar on the river right bank. Right bar apex LWS would be most appropriate, positioned opposite the boulder in the river right bank (see photo), to encourage the development of the proto bar on the river right bank. However, a medial LWS could be used as an alternative due to the shallower channel, positioned towards the river right bank, to enhance channel diversity and provide habitat benefit (i.e. in-channel cover) if land ownership is a constraint. Potential constraint related to different land ownership.	
D40	348975	818361	Medial	Moderate	Wide and homogeneous channel morphology. LWS positioned toward the river left of centre in the channel, to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover).	

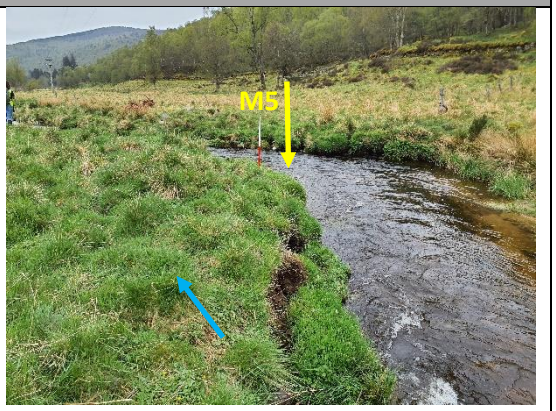
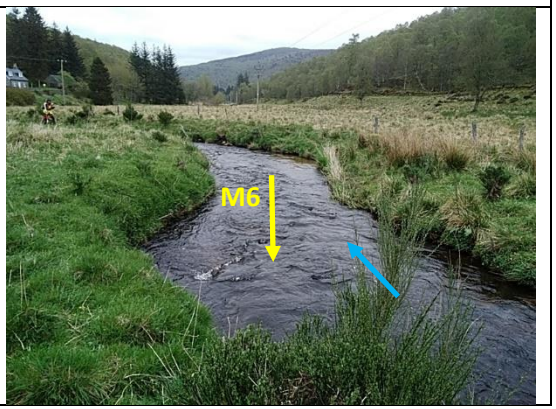
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D41	349024	818408	Right Bar Apex	Moderate	Wide homogeneous channel morphology with localised deposition of a proto bar on the river right bank. LWS positioned 25 m upstream of the trees (see photo) to enhance the development of the proto bar and provide habitat benefit (i.e. in-channel cover). Potential constraint related to different land ownership.	
D42	349048	818434	Right Bar Apex	Moderate	Wide homogeneous channel morphology with localised deposition of a proto bar on the river right bank. LWS positioned at least 2 m downstream of the trees (see photo) to avoid impacting their stability in the bank. LWS aims to enhance the development of the proto bar and provide habitat benefit (i.e. in-channel cover). Potential constraint related to different land ownership.	

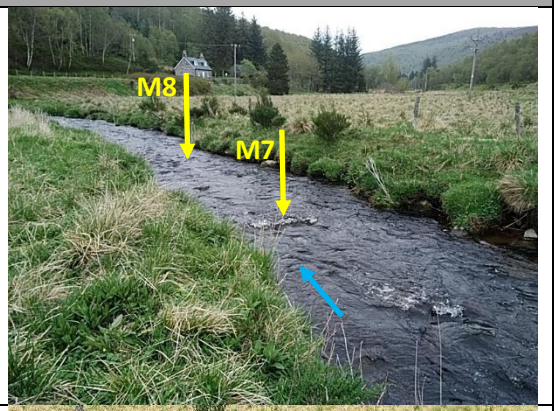
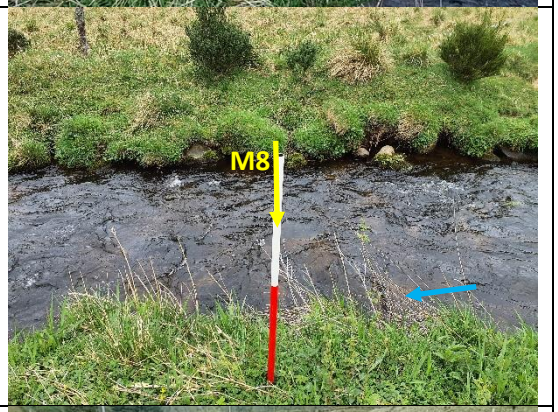
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
D43	349077	818468	Medial	Moderate	Wide homogeneous channel morphology. LWS positioned in centre of channel, to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover). Depth is unknown; if the channel is deeper than 0.75 m, this medial structure could be positioned toward river right where the channel is shallower. If no appropriate depth is found, this LWS should be descoped.	

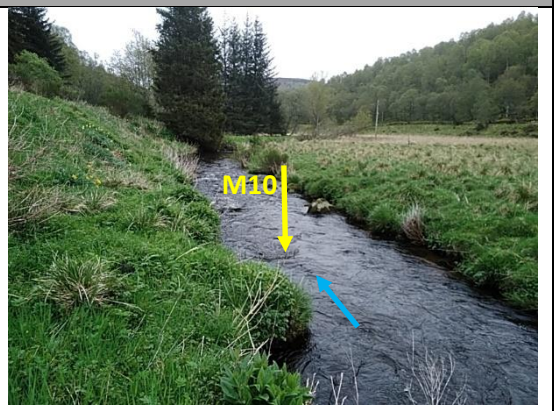
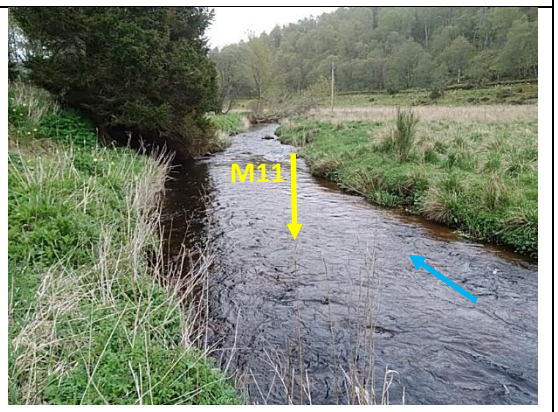
3. MOSSAT BURN (M)

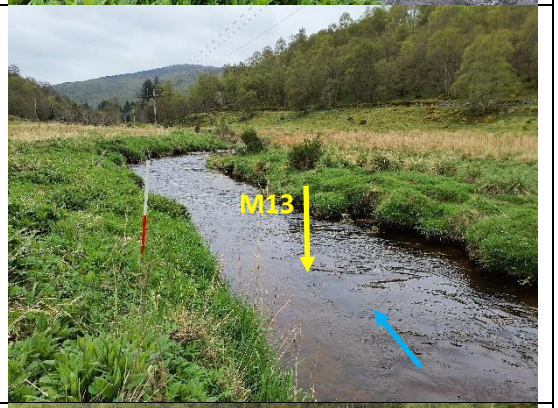
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
Mossat Burn						
M1	348524	818968	Medial	Moderate	Channel substrate lacking gravel and cobble fraction. LWS positioned to encourage deposition, enhance channel diversity and benefit habitat (i.e. in-channel habitat)	
M2	348529	818958	Left Bar Apex	High	Homogeneous channel morphology, lack of lateral bars, impeding connection to the floodplain. LWS positioned to encourage the formation of a point bar where one would be expected to form with the aim to enhance channel diversity and improve connectivity between the channel and floodplain.	

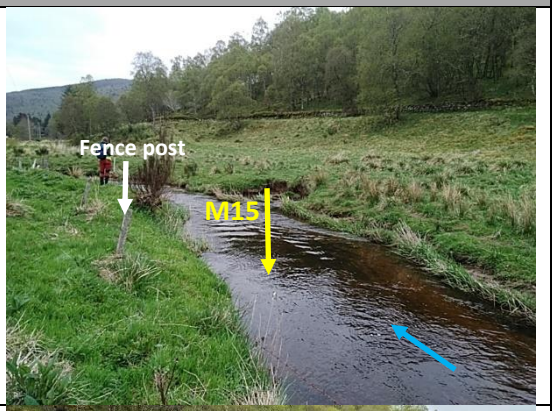
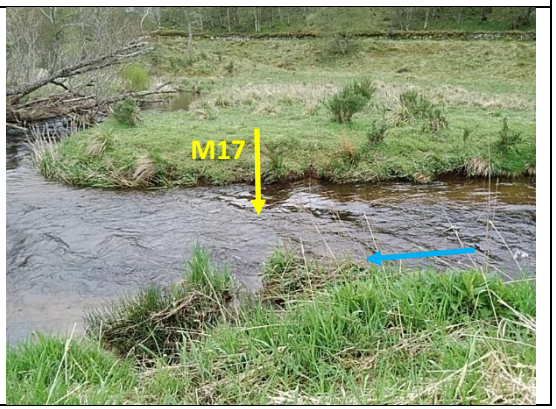
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M3	348534	818947	Medial	Moderate	Wide and relatively homogeneous morphology. Submerged proto bar present in centre of the channel, forming around vegetation. LWS positioned to enhance development of the proto bar and enhance in-channel habitat (i.e. in-channel cover).	
M4	348545	818935	Right Bar Apex	High	Proto bar present on river right bank. LWS positioned to encourage development of the proto bar on the river right bank and encourage flow towards river left bank to increase sinuosity. This LWS requires the collapsing telegraph pole to be moved, ideally set back from the channel on the river right bank to allow space for lateral channel adjustments and increased sinuosity.	

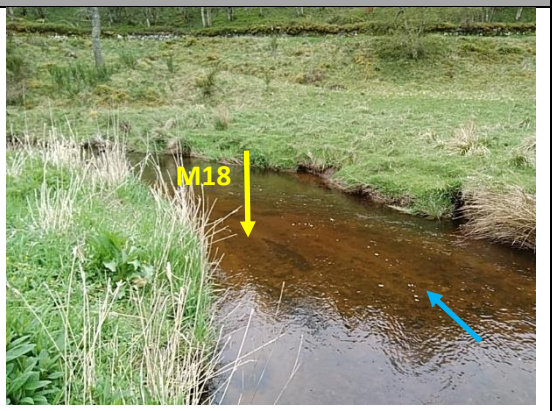
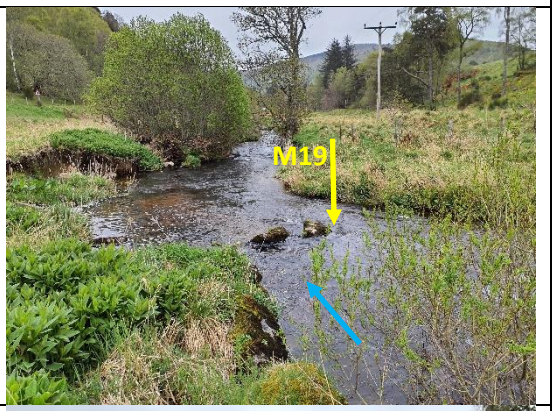
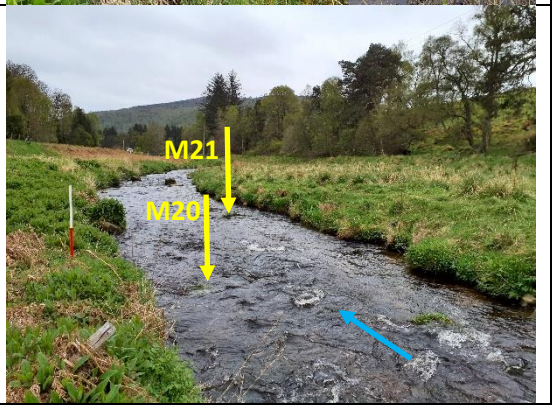
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M5	348555	818923	Left Bar Apex	High	Proto bar present on river left bank and disconnected side channel on river right floodplain. Position LWS to enhance development of the proto bar and increase sinuosity, also to help reactivate the side channel with the aim to improve connectivity between the floodplain and the channel . Existing rock bank protection should be removed on the river right bank to allow for channel adjustment.	
M6	348582	818916	Medial	High	Medial proto bar present behind existing boulder. LWS positioned to river right of the submerged boulder (see photo) to enhance development of the proto bar and promote widening of channel.	

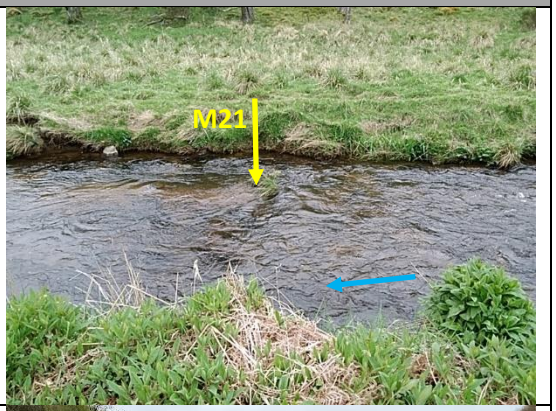
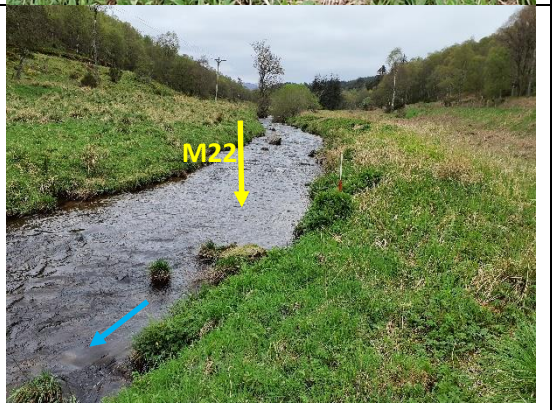
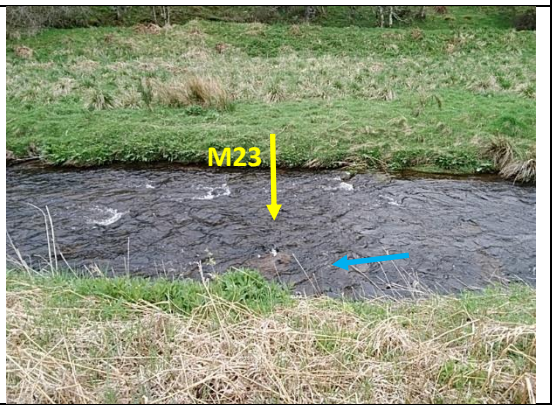
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M7	348597	818908	Medial	Moderate	Homogeneous channel morphology. LWS positioned to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover). Existing rock bank protection should be removed on the river right bank to allow for channel adjustment.	
M8	348603	818908	Medial	Moderate	Homogeneous channel morphology. LWS positioned to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover). Existing rock bank protection should be removed on the river right bank to allow for channel adjustment.	
M9	348632	818921	Right Bar Apex	Low	Homogeneous channel morphology. LWS positioned in the river left branch of the channel where it splits around an island to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover).	

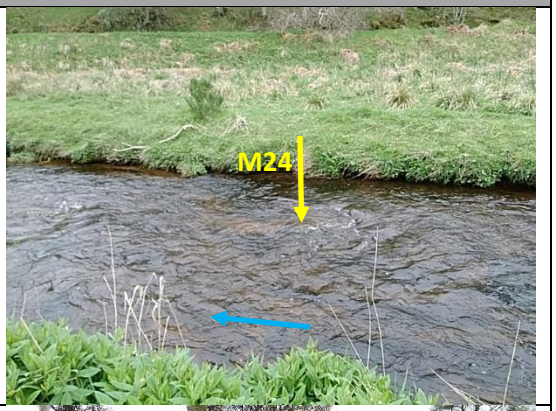
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M10	348678	818889	Medial	Low	Homogeneous channel morphology with localised deposition of a medial proto bar. LWS positioned downstream of the nearby telegraph pole, towards river left to encourage development of the proto bar and increase channel diversity. Potential access constraints relating to the steep bank between the channel and the road. Potential asset constraints relating to the proximity to the nearby telegraph pole and the road (i.e. erosion risk will require monitoring with the potential need to mitigation measures).	
M11	348697	818872	Medial	Low	Homogeneous channel morphology. LWS positioned to increase channel diversity and enhance in-channel habitat (i.e. in-channel cover). Potential access constraints relating to the steep bank between the channel and the road. Potential asset constraints relating to the proximity to the road (i.e. erosion risk will require monitoring with the potential need to mitigation measures).	

Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M12	348712	818841	Left Bar Apex	High	Homogeneous channel morphology with localised deposition of a proto bar on the river left bank. LWS positioned to enhance the development of the proto bar and increase diversity in the channel.	
M13	348743	818785	Medial	High	Wide and homogeneous channel morphology. LWS positioned increase diversity in the channel and enhance in-channel habitat (i.e. in-channel cover).	
M14	348760	818768	Right Bar Apex	Moderate	Proto bar present on the river right bank. LWS positioned at the upstream extent of the existing river right proto bar to enhance its development.	

Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M15	348785	818738	Left Bar Apex	High	Proto bar present on the river left bank. LWS positioned upstream of the fence post, to enhance the development of the proto bar on the river left bank and provide habitat benefits (i.e. in-channel cover). Paired with downstream LWS D16.	
M16	348791	818733	Left Bar Apex	High	Proto bar present on the river left bank. LWS positioned opposite the downstream extent of the river right scoured bank (see photo). LWS aims to enhance the development of the proto bar on the river left bank and enhance natural scour to the river right bank with the aim to increase sinuosity. Also, this LWS aims to provide habitat benefits (i.e. in-channel cover). Paired with upstream LWS D15.	
M17	348818	818733	Right Bar Apex	High	Proto bar present on river right bank. LWS positioned to enhance development of the proto bar and enhance in-channel habitat (i.e. in-channel cover). Existing rock bank protection should be removed from the river left bank on the outside of the meander bend to allow for channel adjustment.	

Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M18	348827	818707	Left Bar Apex	Moderate	Proto bar present on the river left bank with a well-developed pool already present on river right. LWS positioned to enhance deposition on the proto bar to encourage the development of meander bend channel morphology. LWS currently located within the impounded flow upstream of the weir. Removal of the weir would increase the effectiveness of this structure.	
M19	348856	818694	Left Bar Apex	Low	Proto bar present on the river left bank. LWS positioned to enhance development of the proto bar. LWS only feasible if weir and associated bank protection is removed.	
M20	348901	818671	Medial	High	Wide and homogeneous channel morphology. LWS positioned to the left of centre in the channel to increase diversity of flow and enhance in-channel habitat (i.e. in-channel cover). Positioning should be offset from downstream LWS M21.	

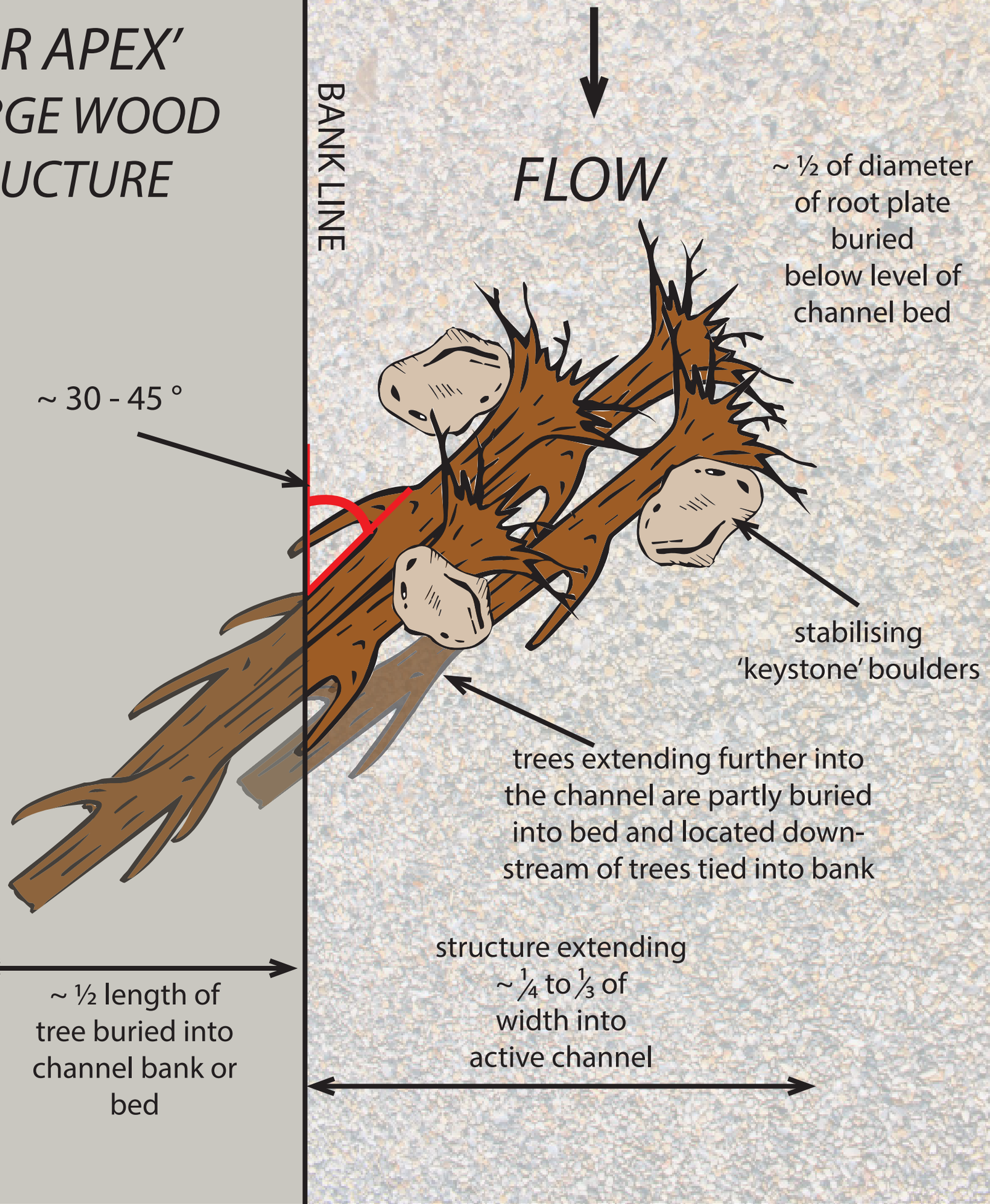
Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M21	348906	818666	Medial	High	Wide and homogeneous channel morphology. LWS positioned to the right of centre in the channel to increase diversity of flow and enhance in-channel habitat (i.e. in-channel cover). Positioning should be offset from upstream LWS M20.	
M22	348933	818648	Left Bar Apex	High	Wide and homogeneous channel morphology with localised deposition of a proto bar on the river left bank. LWS positioned upstream of the boulder on the river left (see photo), to enhance the development of the proto bar and increase channel diversity.	
M23	348951	818621	Medial	High	Wide and homogeneous channel morphology. LWS positioned in the centre of a wider section of channel to increase diversity of flow and enhance in-channel habitat (i.e. in-channel cover).	

Structure Number	Easting	Northing	Type	Priority	Comments	Location Yellow arrow = LWS Root Plate Position Blue arrow = Flow Direction
M24	348957	818611	Medial	High	Medial proto bar present towards river right bank. LWS positioned towards river right bank next to the submerged large boulder (see photo), to enhance the development of the proto bar and provide habitat benefits (i.e. in-channel cover).	
M25	348963	818601	Right Bar Apex	Low	Proto bar present on the river right bank. LWS positioned towards river right bank to enhance the development of the proto bar and increase sinuosity. Also, to provide habitat benefits (i.e. in-channel cover). Constraint related to the telegraph pole located 3 m from the river right bank. Increased sinuosity could pose a future erosion risk to the telegraph pole.	

APPENDIX B

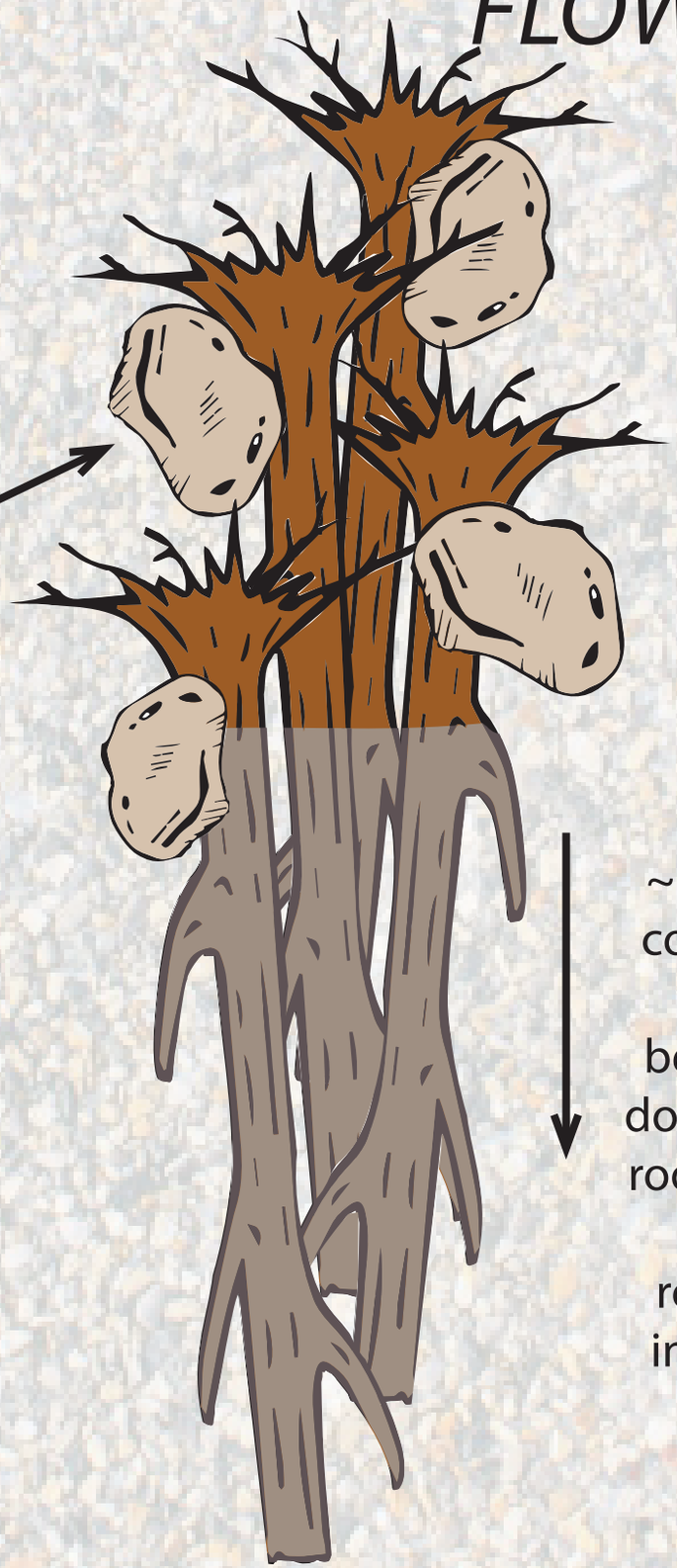
INDICATIVE DESIGN DRAWINGS

'BAR APEX' LARGE WOOD STRUCTURE



'MEDIAL' LARGE WOOD STRUCTURE

FLOW



stabilising 'keystone' boulders

~ ½ length of tree completely buried within channel bed - trees angled down into bed from root plate to crown.
~ ½ diameter root plate buried into channel bed.