Restoring the Slugain Burn

Cairngorms National Park Authority

cbec eco-engineering UK Ltd

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1. INTRODUCTION

The lower reaches of the Slugain Burn, (a tributary of the River Dulnain) in the Spey catchment, near Carrbridge in the Scottish Highlands, have been artificially constrained through historical straightening, with embankments significantly constraining the channel on both sides. This has impacted natural fluvial processes, which in turn has altered the physical habitat of these sections of river. These changes have limited the ecological diversity of the burn and resulted in both the disconnection of the burn from its adjacent floodplain and the periodic deposition of large volumes of sediment within the channel. Localised flooding has increased in recent years (in particular, it is understood that the burn has breached its eastern bank twice since 2019), resulting in costly repairs and maintenance and negatively impacting access for the estate and the local community.

cbec has been commissioned by the Cairngorms National Park Authority (CNPA) to undertake a feasibility study on the lower stretches of the Slugain Burn where it flows into and over the Dulnain floodplain. This report describes the development and appraisal of a range of sustainable restoration options to address the heavily degraded lower reaches of the Slugain Burn.

The overall aim of the feasibility study is to develop nature-based solutions to deliver morphological improvements, restoring physical (geomorphic) and ecological processes within the lower reaches of the Slugain Burn. Where possible, restoration options have been developed to improve access in the area for the estate and recreational users by addressing the current unsustainable management of the sediment that periodically blocks the bridge within the restoration site. In developing the restoration options, the project also aims to raise awareness within the local community of the many benefits of river restoration, such as a greater level of harmony between land use and natural river processes, an increase in habitat and associated biodiversity and a river corridor that is more adaptable to the effects of climate change.

The work forms part of Heritage Horizons: Cairngorms 2030. Funded by the National Heritage Lottery Fund, the project aims to make the Cairngorms National Park an exemplar of people and nature thriving together in a rapidly changing world by 2030. It is understood that this feasibility study forms part of the overarching development phase of the project. A second phase for detailed design and construction is anticipated to start in Autumn 2023.

1.1 APPROACH

Options to improve the degraded nature of the lower reaches of the Slugain Burn have been developed and assessed by applying a robust options identification process and evaluating the resulting options within the context of the wider catchment as well as the section of the burn to be restored. Data from previous work undertaken by cbec in the catchment, desk-based assessments (including ecology information provided by the project group) and information from a field-based fluvial audit and topographic survey were used to develop an understanding of the current physical condition and constraints of the site. This allowed for an informed assessment of potentially feasible restoration options. An on-site meeting was undertaken prior to the field surveys taking place, with all project partners present including landowners, regulatory authorities and land managers. This meant that key requirements and constraints could be fed into the options development process at an early stage. McGowan Environmental Engineering Ltd also attended this meeting to ensure issues such as site access and buildability were accounted for at an early stage in the options development process.

To develop sustainable, long-term restoration solutions for the site, the project team adopted a 'process-based' approach, allowing nature-based options to be developed within the context of the physical process regime of the wider catchment. Particular focus was given to options that: minimised future maintenance costs and requirements; encouraged a longer, more sinuous course for the burn, increasing the diversity of habitats available; and reduced downstream flood risk. The core principle underpinning this approach is that addressing the processes of water and sediment supply, transport and storage at the largest possible spatial scale (i.e. catchment scale) will permit the river to recover naturally towards a dynamically stable morphology that is self-sustaining and requires minimal post-implementation management intervention over the long term. Since physical form and processes provide the template for many critical ecological functions (and their associated biota), it is reasonable to assume that restoring physical form and process should provide medium-to-longer term benefits to the currently degraded aquatic and riparian biodiversity of the Slugain Burn.

What is the 'process-based' approach?

We base our approach on the philosophy of 'process-based restoration'. The underlying concept of the theory is that consideration of the natural geomorphic processes acting at the site will permit the development of a restoration strategy that is appropriate to imposed physical conditions and, where appropriate, permit recovery of the river to a more diverse and self-sustaining condition. In this way, the river itself will subsequently do the work of maintaining a 'natural' and dynamic environment with minimal requirement for subsequent intrusive interventions. It is important to note that the application of this type of 'natural' or nature-based approach to river works (i.e. working with natural river processes) is regarded favourably by the regulator in terms of licensing.

Following the development of an initial list of options for the site, feedback was sought from the project group and was used to refine and finalise the preferred list of options for the site.

1.2 SITE LOCATION

The Slugain Burn rises from a bealach between the hills of Garbh-mheall Mor and Carn Sleamhuinn (NGR NH 842 165) and extends a total of 4 km from its headwaters to the confluence with the River Dulnain at OS NGR NH 854 202, ~5.5 km to the west of the A9 road bridge as it passes close to the village of Carrbridge. The specific study site considered here encompasses the confluence of the Slugain Burn with the Dulnain and ~300 m of the Slugain Burn upstream of the confluence. At its confluence with the Dulnain, the Slugain Burn has a catchment area of 5.4 km^2.

A field-based fluvial audit and topographic survey were conducted throughout the study site and an extended section of the Slugain Burn, along the mainstem Dulnain immediately downstream of the confluence with the Slugain Burn and throughout the wider floodplain. The extended surveys were undertaken to gain information on processes and features outside of the restoration site that may be impacting on it or being impacted by it and to ensure consideration of processes at work within the wider system.

An overview of the study site is provided in Figure 1.1.

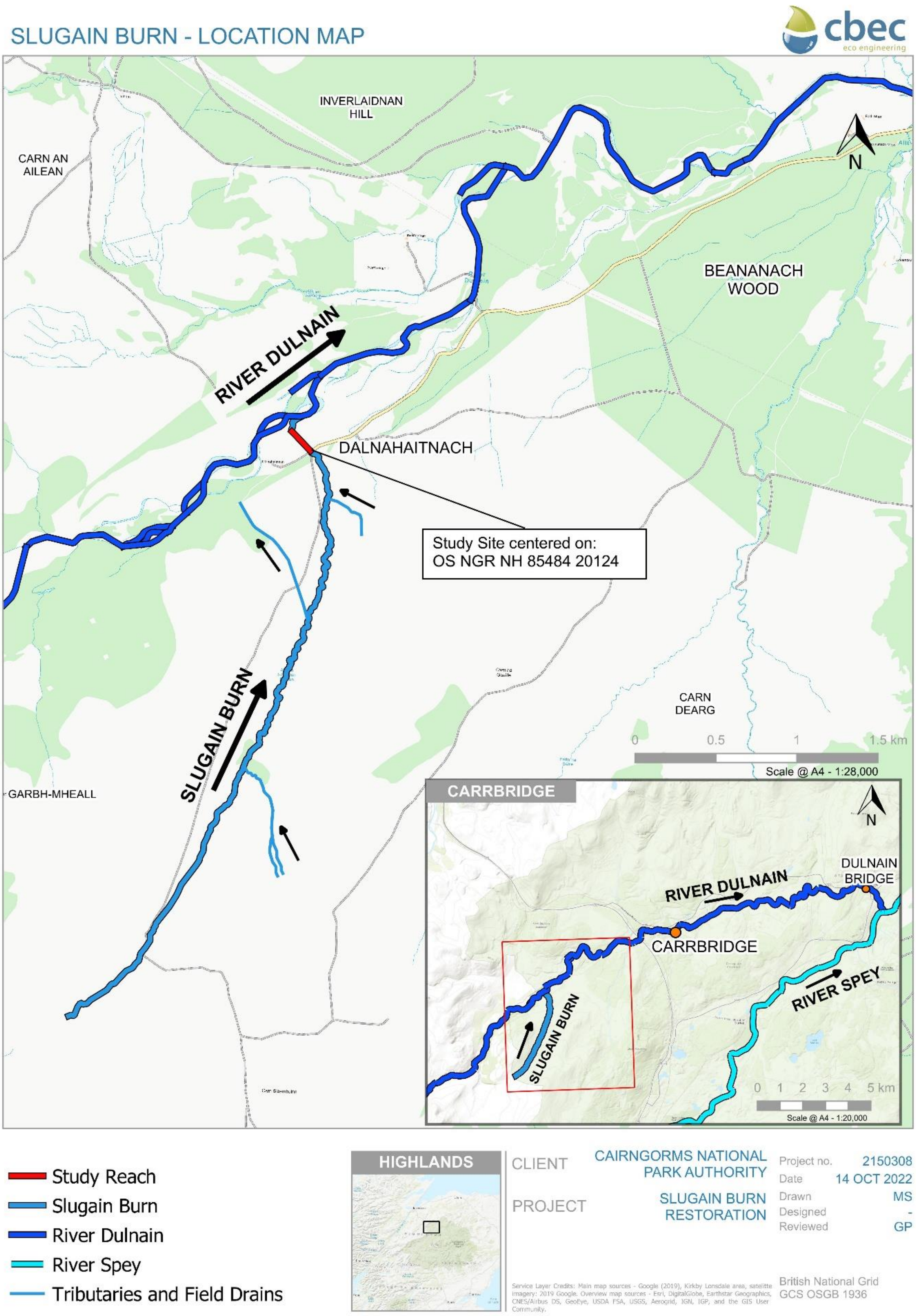

Figure 1.1. Slugain Burn – site location.

2. DATA REVIEW

The specific character of a section of river is influenced by both catchment- and reach-scale processes. Accordingly, it is important that any local channel management decisions are made with a full understanding of the wider catchment. This desk-based data review considers topography, land use, geology, soils and hydrology (including flooding) as a foundation for the subsequent field-based geomorphic survey (i.e. fluvial audit) and to develop suitable restoration options. The assessment also considers any existing data relating to the sites, including a review of historical mapping for the reach of interest.

2.1 PREVIOUS STUDY

cbec previously undertook a study, in 2013, to develop potential options for the restoration/management of the Slugain Burn[1] in the reach of interest. The overarching aim of this previous study was to provide options for the sustainable restoration of physical and ecological processes within the study site, to offer benefits including: a greater level of harmony between land use and natural river processes; an increase in habitat and associated diversity; a river corridor that is more adaptable to the effects of climate change; and an improved understanding within the local and wider community of these benefits and their importance to society.

cbec's report describes the Slugain as being relatively confined in its upland section and significantly realigned/confined where it flows across the Dulnain floodplain. The site has experienced considerable management over at least the last 135 years, including drainage improvements for agriculture, particularly in relation to the now-derelict farm ~200 m west of the Slugain channel. The low-clearance bridge that the Slugain flows under upstream of its confluence with the Dulnain results in a backwater effect during high flows. This has induced significant deposition/aggradation near the bridge; periodic dredging is known to have been undertaken to remove this material, which has been piled on the adjacent channel banks. The channel is described as exhibiting a transitional step-pool/plane bed morphology in the upper reaches and a forced plane bed reach downstream. Prior to management of the channel and the adjacent floodplain, it is considered that the Slugain Burn would likely have had a 'wandering' or 'braided' character, with large active gravel bars resulting in a divided channel morphology. cbec's report notes that the watercourse flows over a characteristic alluvial fan feature that it has created over the last 10,000 to 15,000 years, with the channel periodically switching laterally across the feature in response to sediment deposition patterns. However, recent human intervention is considered to have impacted these natural processes significantly; in particular, canalisation of the channel has been maintained through periodic dredging focused on the section immediately downstream of the road bridge, in an attempt to address the systematic aggradation that had resulted in the bed of the Slugain being elevated above the adjacent floodplain at the time of the cbec study. This canalisation and embanking has artificially increased forces on the channel bed during high flow events, thus impacting the sediment transport regime, increasing channel confinement (i.e. disconnecting the channel further from its floodplain) and reducing in-channel morphology and habitat diversity.

[1] 'Dulnain Tributaries Restoration Project Part 2 : Allt an t-Slugain Dhuibh', cbec report for the Cairngorms National Part Authority, January 2013.

The report concludes that the Slugain Burn has potential for dynamic behaviour, implying that dynamic river processes can be reinvigorated by the removal or relaxation of artificial constraints to dynamic process. On this basis, three potential restoration options were presented:

1. *Full restoration*: removal of all existing constraints (i.e. embankment, existing bridge, some of road) affecting the current channel downstream of the point at which it enters the Dulnain floodplain, constructing an initial new channel just to the east of the existing alignment and allowing the river to develop a more natural equilibrium morphology over time;
2. *Medium restoration*: retention of the existing channel upstream of the bridge and development of a 'transitional' section downstream of the bridge to train the channel into a zone further downstream in which lateral constraints would be removed and more natural process and form reinvigorated.
3. *Low restoration*: widening of the active channel corridor by setting back the existing embankments on one side or both sides of the current channel, constructing a new initial channel through the widened corridor and allowing the channel to evolve over time within the established river corridor.

The 2013 report recognised that there may be considerable barriers to implementation of these options. For example, the removal of the existing infrastructure required for option (1) would likely prove to be a practical constraint in terms of access, while differences in elevation between the channel bed and the adjacent floodplain would make the implementation of option (2) technically challenging and could result in limited restoration of natural process and form. Implementation of option (3) would have low impact on existing infrastructure but would pose some risk of excessive aggradation in future and of failure of the set-back embankments.

Since cbec's previous study was undertaken, the scope of possible restoration and management has widened considerably, with potential for restoration of natural form and process across a much wider area of the River Dulnain floodplain, providing opportunity for much larger-scale gains in terms of natural geomorphic process, wider biodiversity, flood risk, climate change resilience and access and amenity value, among other factors. Given the potential benefits of larger-scale restoration and management options (e.g. realignment of the Slugain Burn across the wider floodplain, relative to a much shorter realignment following the course of the existing watercourse), the options provided in cbec's 2013 report have not been reconsidered explicitly here.

2.2 TOPOGRAPHY AND LAND USE

Catchment topography influences how rapidly the system responds to rainfall, affects the energy of the resulting flows and controls the sediment transport regime within the system. Land use and land cover patterns within a catchment control the influx of water, sediment and large wood to the system.

The burn is a small, upland waterbody that rises near Garbh-mheall Mor and Carn Sleamhuinn at approximately 500 mAOD. The confluence of the burn with the River Dulnain, ~4 km downstream of its headwaters, lies at an altitude of approximately 310 mAOD. The Slugain Burn catchment upstream of its confluence with the Dulnain can be considered an upland catchment. Land use is dominated by moorland in the upper catchment and by forestry and pastoral farming in the lower catchment. The relative lack of woodland in the upper catchment likely results in a limited supply of large wood to the Slugain Burn itself; however, large wood supply to the River Dulnain is likely to be greater, including from a strip of forestry along the southern bank of the Dulnain upstream of the Slugain Burn confluence.

2.3 GEOLOGY AND SOILS

Bedrock and superficial/drift geology (predominantly of glacial origin) and soil cover are important considerations in the development of management options because these factors exercise fundamental controls on sediment availability and the response of the fluvial system to rainfall.

Based on consultation of the British Geological Survey's Geology of Britain viewer[2], the catchment of the Slugain Burn is underlain primarily by the Monadhliath Pluton (Phase 1 and 2), which extends beneath the upstream section of the River Dulnain. The bedrock underlying the lower reaches surrounding the confluence of the Slugain Burn with the River Dulnain and the mainstem Dulnain downstream of the confluence comprises psammites of the Dava Subgroup.

The superficial geology of the catchment comprises, in the upper reaches, the Ardverikie Till Formation, a poorly sorted sediment of stony, sandy clay. Towards the confluence and the mainstem River Dulnain, alluvial deposits underlie the river corridor. Upstream of the confluence on the mainstem River Dulnain, river terrace deposits and glaciofluvial sheet deposits are present. These widespread sediments provide a source of material to be reworked by the River Dulnain.

Based on the Scottish Government's 'Scotland's soils' map[3], the Slugain Burn catchment is covered predominantly by humus-iron podzols; however, mineral alluvial soils underlie the straightened section of the channel that forms the reach of interest and the confluence with the River Dulnain. The extent of the alluvial soils, often associated with high productivity, corresponds well to the areas of fertile, grassland used for agriculture within the River Dulnain valley.

2.4 HISTORIC CHANNEL ADJUSTMENT

Analysis of historical datasets (such as old maps, photos and aerial imagery) adds valuable context to the data collected during field surveys. Such analysis allows evaluation of historic changes in channel planform along the river as the basis for assessing (a) the degree of dynamic behaviour resulting from natural fluvial processes (i.e. as opposed to human activity) and (b) the 'reference state' of the river system. A review of the National Library for Scotland's historical map archive[4] and available aerial imagery was undertaken to provide historical context, including historical channel adjustment and identification of management practices that may have influenced the supply, transport and storage of water and sediment throughout the catchment.

The earliest available mapping for the area surrounding the study site dates from around 1747 (Roy Military Survey of Scotland, 1747-55). However, the high-level nature of this map means that the Slugain Burn has not been captured. The map does, however, provide insight into the large-scale character of the River Dulnain, which is shown to have a sinuous planform in the mapping. The earliest available historical map depicting the Slugain Burn was published in 1875[5] and indicates that the present, straightened channel has been in place since at least this time. A drain is shown on this map adjoining the channel on its western bank that, although not marked on modern day mapping, is

[2] https://www.bgs.ac.uk/map-viewers/geology-of-britain-viewer [Accessed November 2022]
[3] https://soils.environment.gov.scot/ [Accessed November 2022]
[4] https://maps.nls.uk/ [Accessed November 2022]
[5] OS Six Inch Series: Inverness-shire (Mainland), Sheet XLV, Surveyed: 1867-71. Published: 1875.

visible as a depression on satellite imagery. A sluice is marked upstream of the Slugain/Dulnain confluence and appears to have directed flow from the main river into a pond adjacent to the property at Dalnahaitnach. It is possible this represents a mill offtake, with the aforementioned drain acting to discharge mill water back to the main river via the Slugain Burn. The pond is no longer present in historical mapping published in 1902[6]. Furthermore, the 1875 map shows a road bridge crossing the River Dulnain at Dalnahaitnach; this bridge is no longer present, but appears on mapping until at least the 1950s.

Two secondary channels are present on the Dulnain floodplain to the east of the Slugain, arising approximately from and NGR NH 8576 2040 (northern – 'Channel A') and NGR NH 8579 2020 (southern – 'Channel B'); these are indicated in Figure 2.1. These channels join the River Dulnain ~950 m and ~1.5 km, respectively, downstream of the Slugain confluence. Channel A arises within a field ~180 m north of Channel B and exhibits straightened channel sections; Channel B appears similarly straightened. It is considered likely that both channels were originally natural secondary floodplain channels but have subsequently been realigned and deepened to form drains. The historical mapping published in 1902 indicates that the main channel of the River Dulnain previously exhibited a different alignment (Figure 2.1), indicating historical lateral adjustment of the channel. Both Channel A and Channel B are marked on this map, but appear to have been significantly shorter historically. Channel B is now significantly longer due, in part, to the River Dulnain's northward migration but primarily to the extension of Channel B westwards, parallel to the road. Channel A is shown as a minor floodplain side-channel in the historical mapping. In contrast, the Slugain Burn has remained relatively fixed over the period covered by historical mapping, although the location of its confluence with the River Dulnain has moved in association with lateral adjustment of the mainstem channel planform.

2.5 ECOLOGY

The Slugain Burn itself falls within the River Spey Special Area of Conservation (SAC), specifically designated for Freshwater Pearl Mussel, Atlantic Salmon, Sea Lamprey and Otter. Parts of the site are further designated as a Special Area of Conservation (SAC), Special Protection Area (SPA) and an Important Bird Area, particularly the banks of the River Dulnain and a strip of land to the southern side of the minor access road and vehicle bridge. Remnants of old Caledonian pine forest exist on the banks of the River Dulnain and within the wider site there is open moorland habitat. The site is also located within the Kinveachy Forest, which is designated as a Site of Special Scientific Interest (SSSI) due to notified natural features including native pinewood and breeding birds including capercaillie, Scottish crossbills and crested tits.

These designations will be carefully considered during all aspects of the project to ensure that all work undertaken, as well as the final design proposals, contribute positively to the ecological functioning of the site and the designated habitats and species. Initial discussions with the project group and wider stakeholders have also indicated that areas of the floodplain provide important habitat for waders; this will be explored further during the options appraisal process and incorporated into the options matrix.

[6] OS Six Inch Series: Inverness-shire, Mainland XLV, Surveyed: 1900, Published: 1902.

Figure 2.1. Slugain Burn – historical channel alignment as indicated on mapping published in 1902.

2.6 HYDROLOGY/FLOOD RISK

The hydrology of a catchment controls the movement of water through the system and affects the rate and magnitude of any changes in water level and extent. Although the Slugain Burn is ungauged, the River Dulnain benefits from a SEPA level gauge located approximately 1.5 km downstream of the site at Inverlaidnan Bridge (OS NGR NH 8655 2116). The gauge has been operational since February 2017 and the maximum level recorded at the stie was 2.322 m, recorded on 7th August 2019.

The Slugain Burn lies within the Findhorn, Nairn and Speyside Local Plan District and is not located within a Potentially Vulnerable Area. SEPA's Flood Maps indicate that the floodplain of both the Slugain Burn and River Dulnain in the vicinity of the restoration site are inundated during high-likelihood flood events (i.e. the 1:10 year flood). The area with greatest risk of inundation lies across agricultural land just to the east of the straightened channel section. In particular, SEPA's mapping indicates that, during flood events, flood waters arising from the Slugain Burn upstream of the access road flow north and east across the floodplain, forming secondary (high-flow) channels that connect to Channel A and, in particular, Channel B shown in Figure 2.1. The site is at minimal risk of surface water flooding.

Reports from the Project Group suggest that localised flooding has become more frequent in recent years, with the Slugain Burn breaching its eastern bank twice since 2019. Flooding upstream of the current bridge (NH 85552 20054) may be exacerbated by its low clearance, causing water to back up during high flows. Further flooding has been reported due to backing up around the bridge at Inverlaidnan (NH 86539 21162).

SEPA's online Natural Flood Management (NFM) opportunity maps represent a high-level tool for identifying opportunities for the implementation of NFM, including the designation of areas with potential for sediment management. Although these maps do not classify the sediment regime within the fluvial audit reach, they do provide background to the wider River Dulnain environment. They indicate that the confluence of the Slugain Burn with the Dulnain corresponds to a boundary between primarily 'moderate deposition' upstream and 'moderate erosion' downstream, suggesting that the Slugain Burn flows into a channel that is erosion-dominated, potentially with accumulation of alluvial sediment on the River Dulnain upstream of the confluence. These classifications should be considered indicative only and a detailed assessment of sediment dynamics within the Slugain Burn and in adjacent sections of the mainstem River Dulnain will be provided by the fluvial audit. No opportunities for runoff reduction have been highlighted within the study site, although the opportunity maps do indicate medium to high potential for floodplain storage on a section of the eastern bank of the studied reach; these opportunity areas indicate locations in which SEPA's high-level screening has identified the potential for storage of flood waters on the floodplain and the attenuation of flooding based on the natural features of the landscape.

2.7 WFD CLASSIFICATION

Information on Water Framework Directive (WFD) status has been obtained from SEPA's Water Classification Hub. The Slugain Burn is a non-main river and, as such, is not classified under the WFD. The burn does, however, converge with the River Dulnain within the lower reaches of the site. The River Dulnain (WFD Waterbody ID: 23106) is situated within the wider Spey catchment and is approximately 26.5 km long. During the most recent assessment (2020) the waterbody was classified as having 'Good' status. Both the ecological classification and hydromorphological designation are also

'Good'. No existing pressures have been noted by SEPA as part of the WFD classification for the waterbody.

2.8 BRIDGE

Just downstream of the point at which the Slugain Burn meets the floodplain of the Dulnain valley, it flows under a low-clearance road bridge, a feature that appears to result in a backwater effect during high flows. This feature is inducing sediment deposition/aggradation of the bed in the vicinity of the crossing, requiring periodic removal of material that has been stored on the immediate channel banks. Given the significant impact of this bridge on natural river processes, a critical component of this project involves working with Moxon Architects and Highland Council to design a new bridge to replace the current bridge.

2.9 LAND OWNERSHIP

All land likely to be affected by the present project is owned by Seafield Estate, although the land is currently tenanted to a local farmer. The needs of both the landowner and the tenant will be considered at the options appraisal stage and will feed into the appraisal matrix to determine the preferred option.

3. FIELD SURVEYS

3.1 HIGH-LEVEL TOPOGRAPHIC SURVEY

A topographic survey was undertaken to inform options scoping for the restoration/management of the Slugain Burn. A combination of a Trimble RTK GPS and S6 Total Station was used to capture data using a ‘rod-based’ methodology. In areas of the study site where vegetation cover was more prevalent or mature, the Total Station ensured adequate coverage beneath tree canopies.

The main channel of the Slugain Burn was surveyed from upstream of the road bridge at NGR NH 85601 20014, to the confluence with the River Dulnain. This included details of the existing bridge such as the soffit level. Existing road levels were captured from the existing walkers’ car park and along an ~230 m long stretch extending eastwards, including details of adjacent drainage ditches. To inform possible relocation of the walkers’ car park, a coarse-resolution gridded survey of the small, grassy area on the right bank of the Slugain Burn was undertaken.

Initial options for realignment included connecting the Slugain Burn to existing channels or topographic low points within the study site extent. Two main possibilities have been identified, referred to in the historical analysis (Section 2.3) as ‘Channel A’ (northern) and ‘Channel B’ (southern). These channels were captured using channel cross sections spaced approximately 20 m apart, including 5 m of floodplain either side of the main channel. The remaining floodplain area was surveyed in coarse grid format, to allow for the identification of low points at which the realigned channel could be tied in.

The topographic survey points collected are illustrated in Figure 3.1. Following post-processing of these data points, a georeferenced Digital Elevation Model (DEM) was created using Autodesk Civil 3D (Figure 3.2).

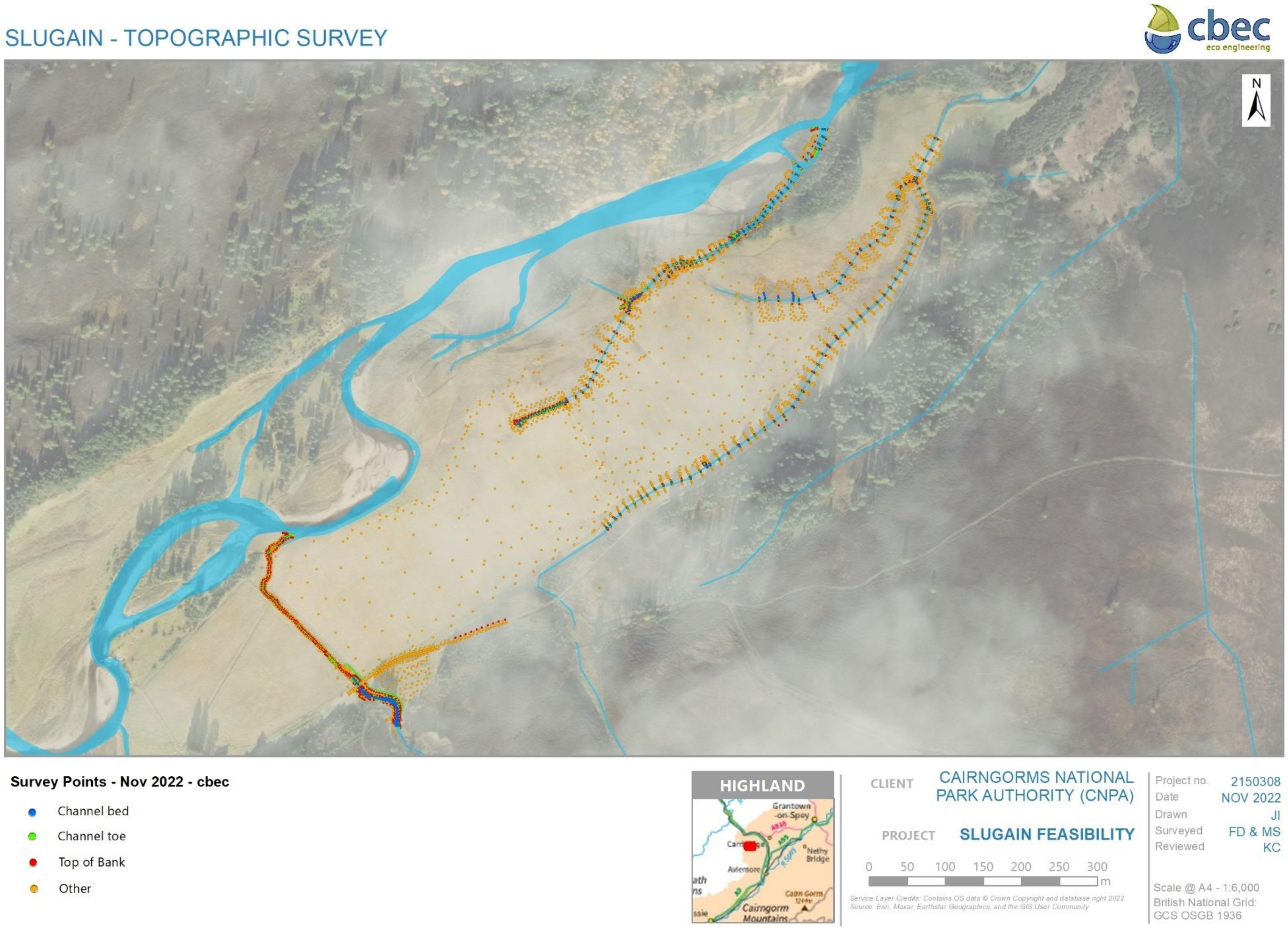

Figure 3.1. Topographic survey points.

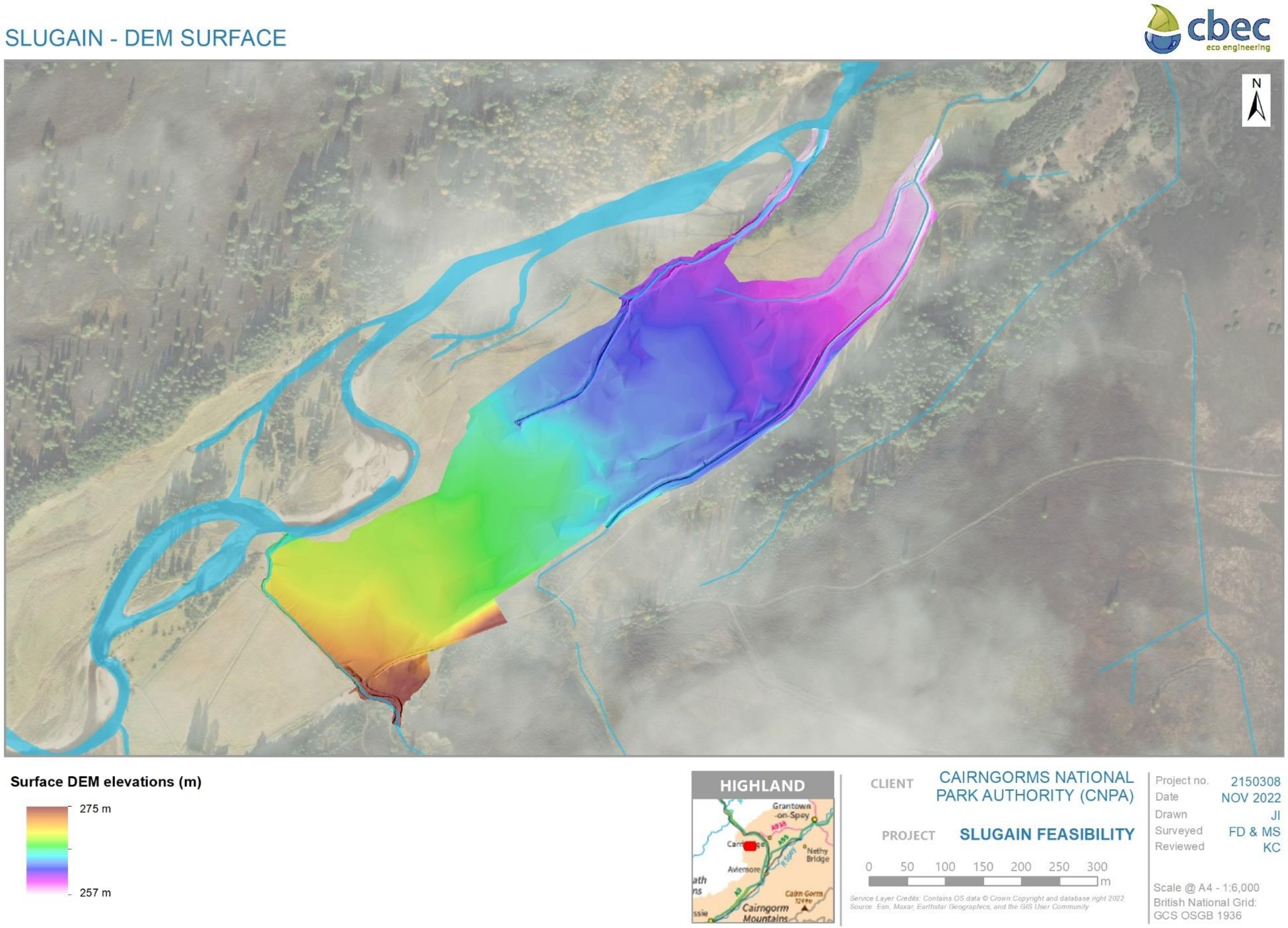

Figure 3.2. Existing conditions DEM.

3.2 GEOMORPHIC ASSESSMENT

3.2.1. Methodology

A field-based geomorphic assessment of the physical condition of ~1 km of the Slugain Burn (from approximately OS NGR NH 8567 1973 to NH 8545 2024) and the surrounding areas of the mainstem River Dulnain and its floodplain was undertaken to assess the distribution of morphological, sedimentary and ecological factors in combination with human impacts along the length of the studied sections. A 'fluvial audit' was undertaken along the Slugain Burn itself, encompassing the historically straightened and embanked section and the sections upstream and downstream. The fluvial audit was undertaken on 15th and 16th November 2022; the weather on 15th November was dominated by blustery showers, while that on 16th November was generally fair. Water levels at the time of the assessment were at the lower end of the normal range. The fluvial audit procedure is a location-specific inventory of the physical form of the river (i.e. morphology and sedimentology) that creates a template for key habitats and all likely influencing factors, providing an understanding of both form and function; this enhances our understanding of the causes of river degradation and supports the implementation of sustainable measures to address such degradation. The less detailed geomorphic walkover assessment was undertaken to allow assessment of the restoration reach in the context of the wider river system, to help define an appropriate 'reference state' for the river and to investigate areas of the floodplain that may be suitable for channel realignment. Information collected included, but was not limited to, the following:

- Reach-scale channel morphology (e.g. step pool, plane bed, pool-riffle, wandering). We use a classification system that is a combination of recognised procedures (i.e. Montgomery and Buffington, 1997; Brierley and Fryirs, 2000).
- Morphological/habitat units (i.e. pools, riffles, runs). These are specific 'mesoscale' features that, together, define reach-scale morphology. Such features can be regarded as the fundamental physical 'building blocks' of river channels and are closely related to habitat patterns. Therefore, such data can provide potentially valuable information to support assessments of ecological condition and habitats.
- Indicators of the sediment transport regime (e.g. the size, form, texture, dominant particle size and vegetation cover of bar features and bed forms). This information is essential for interpreting physical process within the river and has implications for ecological condition and habitats.
- Sediment sources (e.g. from upstream on the main river, tributaries, bank/terrace erosion). These sources have been recorded in terms of severity and extent.
- In-channel sediment storage (including alluvial bar features and evidence of bed accumulation). This data also provides an indication of the rate and distribution of sediment supply to downstream areas from within-channel sources. This includes any indicators of sediment transport (e.g. the size, form, texture and vegetation cover of bar features and bed forms).
- Large wood. The incidence, location (e.g. mid-channel, bank-side) and extents of large wood within the active channel, including their physical and ecological influence, have been documented.
- Vegetation. Both in-channel vegetation (e.g. macrophytes) and riparian/bank-side cover have been recorded, as well as invasive/non-native species.

- River engineering pressures (e.g. weirs, lades, impeded side channels, bank protection, canalisation, embankments, bridge crossings). These features have been characterised in terms of their extents and the severity of their impacts on river process.
- Floodplain morphology, including drainage channels/ditches, relict natural secondary channels, wetland areas and swales.
- Other indicators of the dynamic physical behaviour of the channel (e.g. abandoned channel courses, historic side channels, age structure of vegetation within the riparian corridor).
- Other land use pressures in the areas draining directly into the watercourses surveyed (e.g. urban drainage, livestock poaching, poor forestry drainage, field cultivation close to channel margins).

The collected data were recorded using a mobile GIS platform, Qfield, with integral GPS capability. This allowed accurate determination of the position and extent of important features (e.g. length of bank erosion, areas of sediment stored in active bar features). High-resolution georeferenced photos were also taken throughout the survey reach to capture significant features/structures and illustrate the general character of specific reaches.

3.2.2. Assessment of Fluvial Form and Process

For the purposes of the fluvial audit, the Slugain Burn has been divided into two separate reaches based on differences in boundary conditions. The upper reach is characterised by a high degree of lateral confinement by steep valley slopes, while the lower reach is naturally unconfined but artificially constrained by embankments. The dominant features of each reach are summarised in Table 3.1 and Table 3.2, with maps provided in Figure 3.3 and Figure 3.4. A reconnaissance-level survey/targeted walkover of the mainstem River Dulnain and several drainage and backwater channels was also undertaken to determine the character of the Dulnain and to assess the potential for the drainage channels to be incorporated into any channel realignment options. The general areas covered by this walkover are illustrated in Figure 3.5. The River Dulnain here is a highly dynamic gravel-bed river exhibiting a wandering morphology, with extensive alluvial deposition, particularly in the form of point bars, and erosion along the outsides of meander bends. The channel is often split around active to stabilised gravel islands and there is evidence of lateral migration of the main channel and activation of secondary channels during flood events. Based on field evidence and aerial photos, the backwater channel is likely connected to the Dulnain during high flows. Under normal conditions, the backwater channel has standing to slowly flowing water along much of its length and flows alongside an area of native woodland in its lower sections. The channel is incised in places but otherwise represents an area of existing good habitat; for this reason, and owing to the potential for the Dulnain to avulse into this channel, the backwater channel is not considered further as a potential option for an alternative route for the restored Slugain Burn. In contrast, both Channel A and Channel B are considered to offer good restoration potential. Both are currently straight, incised drainage ditches along much of their length and could be naturalised and tied into a realigned Slugain Burn; both channels already have confluences with the River Dulnain, although the confluence of Channel B with the Dulnain is protected by extensive hard bank protection and flow along this channel is variable. A smaller ditch flows into Channel B in the middle of the large floodplain area; although this ditch hasn't been considered explicitly in the optioneering process, there would also be potential to connect a realigned Slugain Burn here if naturalisation of the full extent of Channel B were to be ruled out due to existing constraints.

Table 3.1. Summary of fluvial form and process: Reach 1.

<table>
<tr><th colspan="2">Reach 1: Slugain Burn (upstream)</th></tr>
<tr><td>

Reach type, units and boundary conditions

- confined channel with steep valley sides, becoming less confined at downstream end
- generally single-thread channel, tending to multi-thread where valley floor widens locally
- predominantly transitional step pool/plane bed reach type with tendency towards pool-riffle morphology where valley floor less steep with small floodplain areas
- bed substrate primarily cobble/boulder with cobble/gravel sections locally
- variety of morphological units, generally poorly defined and controlled by coarse bedforms
- pools and glides locally where steps more well developed or channel straighter
- more well-defined pools, riffles and runs in pool-riffle sub-reach

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Typical units and valley form


Typical units and valley form


Typical units and valley form


Coarse material piled along channel margins

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Morphological pressures

- no obvious morphological pressures
- historical bank protection may be present in some locations – evidence of coarse sediment having been piled along banks in place
- embankment starts at downstream end of reach

</td></tr>
</table>

Erosion and deposition

- well-defined alluvial bar forms in pool-riffle sub-reach, partly stabilised
- poorly developed, very coarse lateral and medial bar forms elsewhere
- severe erosion on outsides of bends, oversteepening valley sides
- minor to moderate bank erosion elsewhere
- some evidence of minor incision into cobble/boulders bars/berms

Large wood and vegetation

- large wood observed in channel in several locations
- trees in channel margins towards downstream end of reach
- hillslope vegetation predominantly open moorland/heathland with scattered trees

Sediment supply

- coarse sediment (gravel to boulder size) being supplied from headwater reaches upstream
- cobbles, gravel and fines being supplied from severe bank erosion (hillslope coupling)
- fines and gravel/cobbles being supplied from more moderate toe erosion


Severe bank erosion and medial deposition


Small floodplain near downstream end


Large wood and coarse sediment in channel


Channel near downstream end

Table 3.2. Summary of fluvial form and process: Reach 2.

Reach 2: Slugain Burn (downstream)

Reach type, units and boundary conditions

- valley floor less steep and unconfined
- single-thread channel owing to constraints
- plane bed/step pool morphology upstream of bridge and plane bed downstream
- pool-riffle/plane bed transitional reach downstream where channel not constrained
- bed substrate primarily cobble and cobble/gravel, with gravel/cobble near confluence with Dulnain
- riffle/run units upstream of bridge, glide in constrained plane bed section
- more well-defined riffles, runs, pools and glides in pool-riffle/plane bed section

Morphological pressures

- extensive embankments to river left and right, composed largely of dredged material
- embankment to river right breached near upstream end, with high-flow pathway evident across river right floodplain
- embankment higher and unvegetated immediately downstream of bridge, indicating extensive dredging in the past
- embankment also present along road, beside ditch that conveys high flow
- vehicle bridge, with some hard bank protection present upstream
- bridge capacity insufficient to convey flow and is reduced by build-up of sediment


Typical units and valley form (upstream end)


Typical units and valley form (embanked section)


Typical units and valley form (downstream end)


High-flow channel, river right floodplain

Erosion and deposition

- limited deposition in upper parts of reach, although dredged material has been dumped along both banks upstream of bridge to form berms
- alluvial bar forms common in pool-riffle reach
- banks generally stable, with no notable bank erosion, except at Slugain/Dulnain confluence

Large wood and vegetation

- very limited large wood in channel
- some trees present in channel margin/along embankment
- floodplain dominated by grazing, with some woody vegetation near confluence with Dulnain

Sediment supply

- coarse sediment supplied from upstream
- very limited supply of fines from minor localised toe erosion
- sand and gravel deposits on floodplain near confluence (possibly from mainstem Dulnain)
- channel has been dredged and aggradation continues to be ongoing, with channel bed higher than floodplain in places


Bridge and bank protection (right bank)


Berms (dredged material) upstream of bridge


Embankments (looking upstream)


Ditch and embankment along road

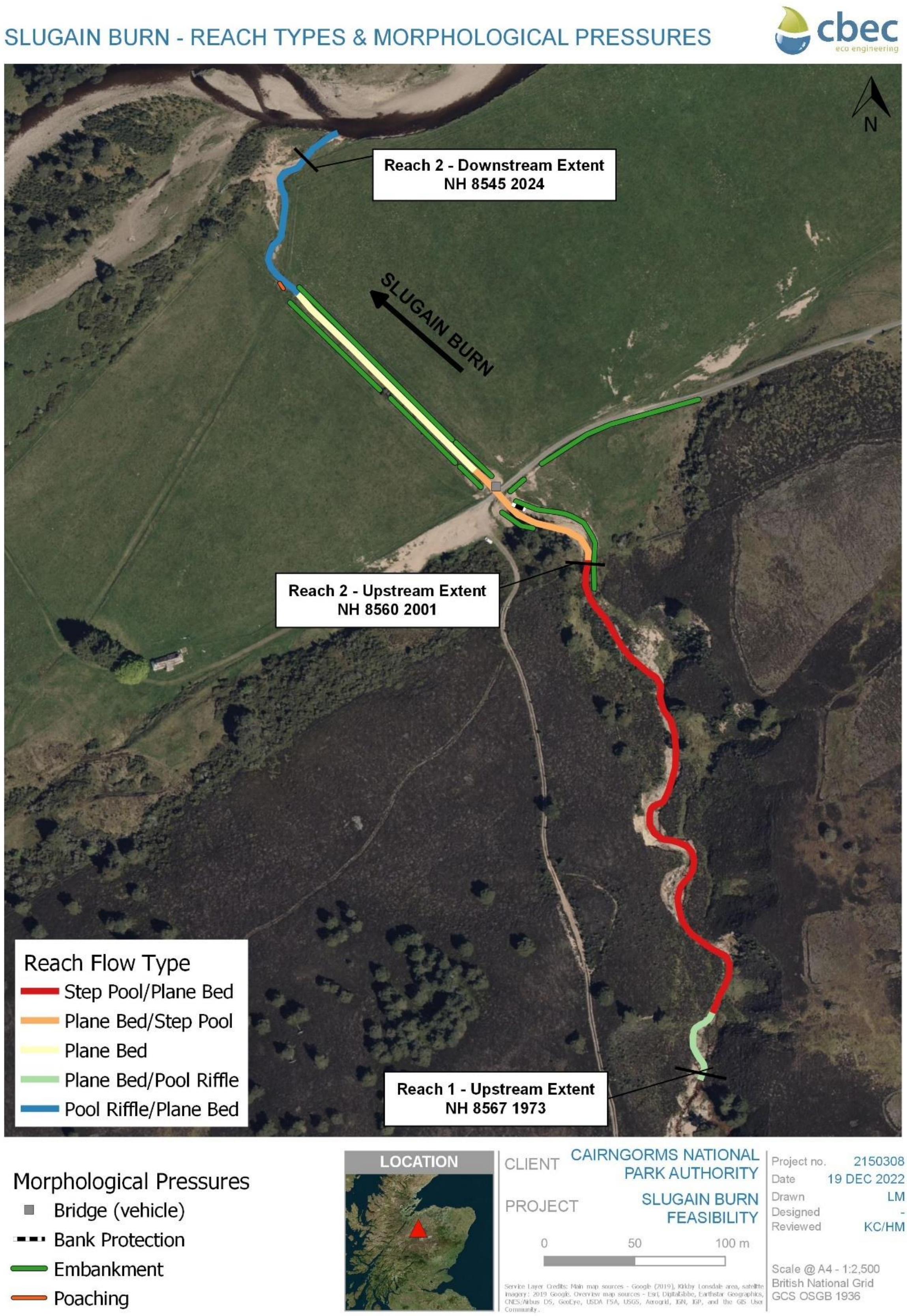

Figure 3.3. Reach types and morphological pressures.

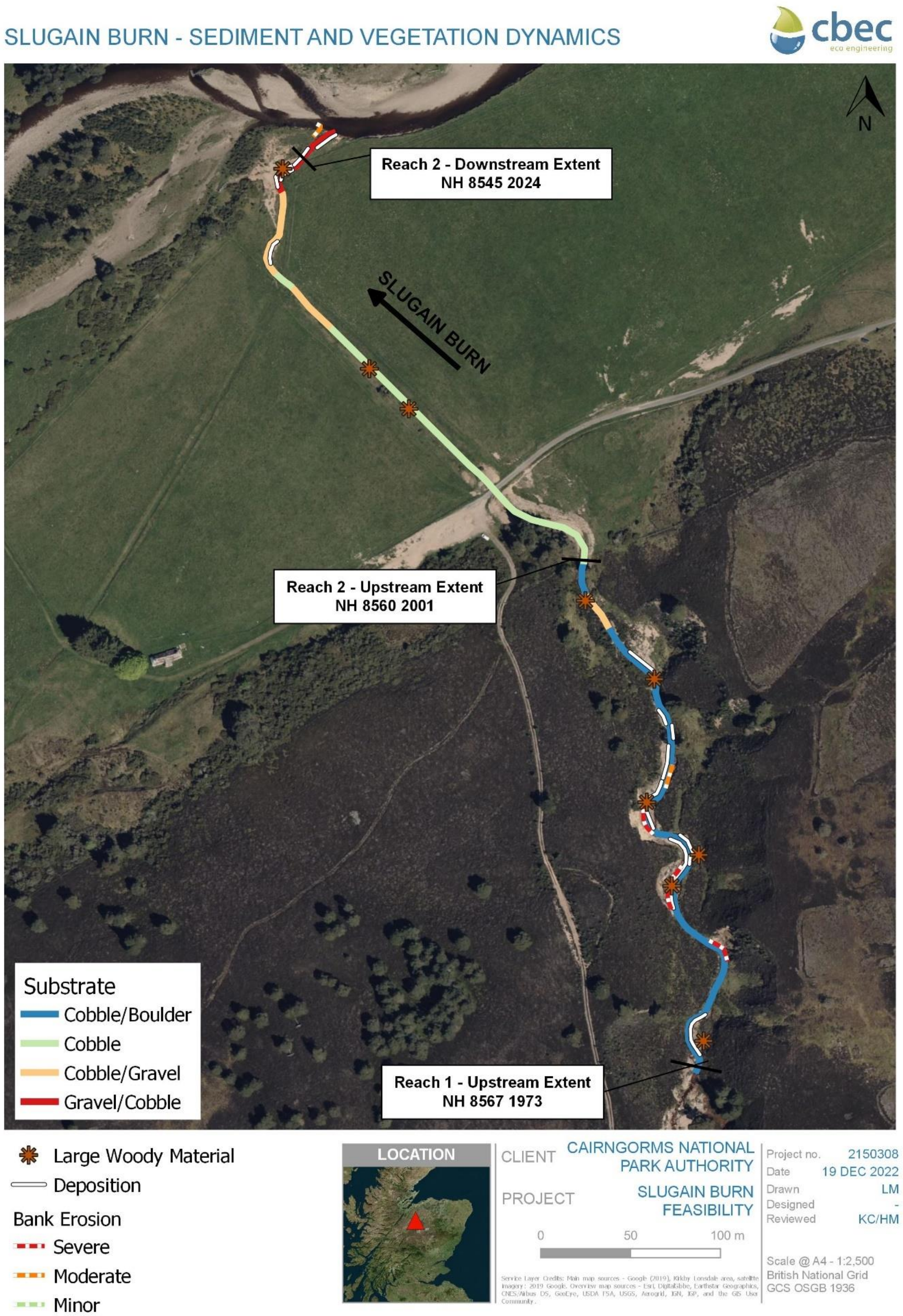

Figure 3.4. Sediment dynamics and large wood.

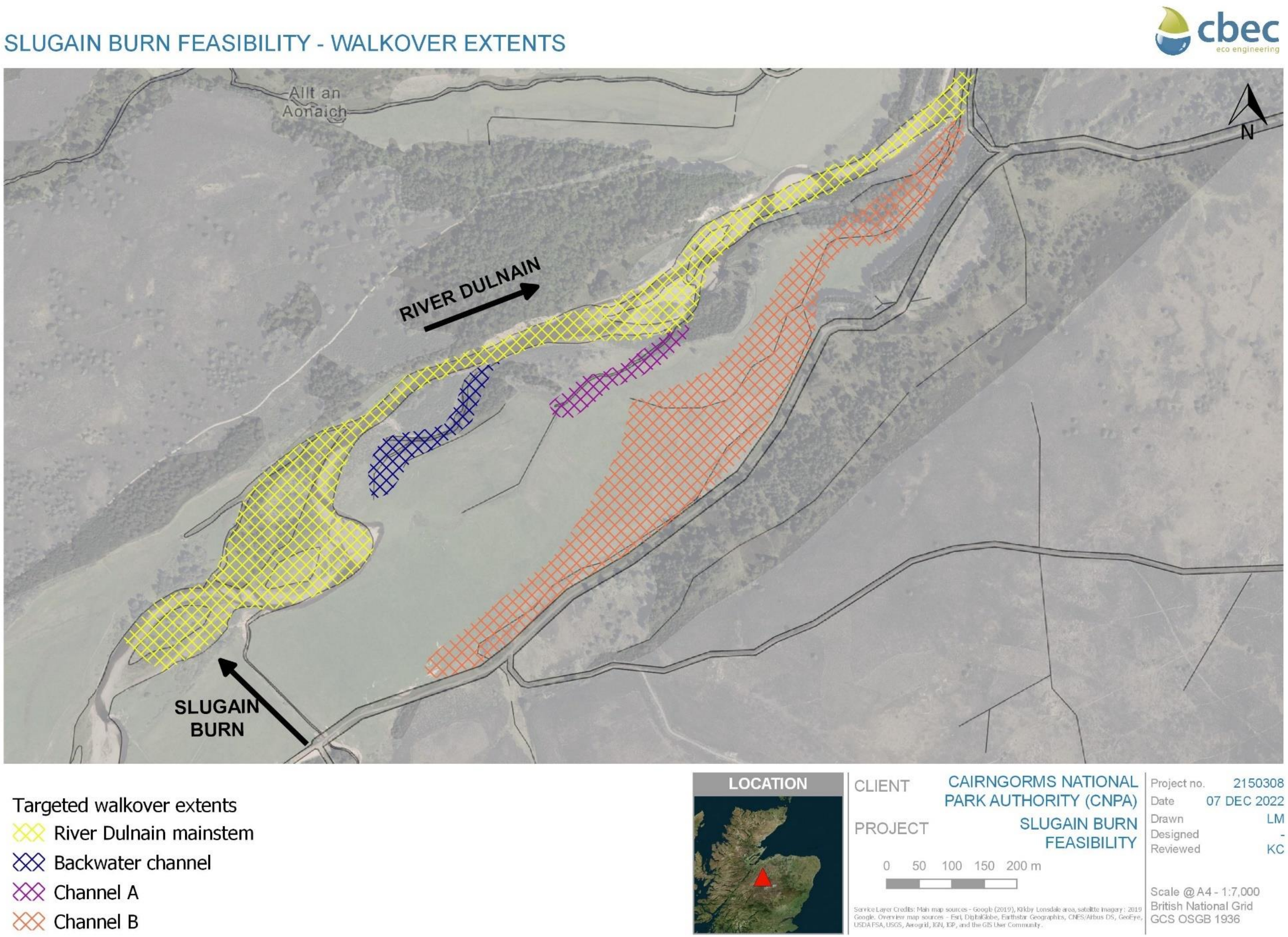

Figure 3.5. Areas covered during the reconnaissance-level survey.

Table 3.3. Photos illustrating character of mainstem River Dulnain and backwater and drainage channels.

Photos from reconnaissance-level survey


River Dulnain general character


Backwater channel general character


Channel A in upstream part


Channel A confluence with Dulnain


Channel B in upstream part


Confluence of channel B with Dulnain

4. OPTIONS DEVELOPMENT

4.1 OPTIONS APPRAISAL

Based on collated desk- and field-based data, four potential options are presented here. As discussed in Section 2.1, the shorter realignment options presented in cbec's 2013 report have not been considered explicitly here given the much greater benefits that can be realised by implementing the longer realignment options that are now possible given the expanded scope of the study. Additionally, maintaining the watercourse along its current alignment (i.e. the 'Do Nothing' approach) is not considered to be a feasible option given the risk posed to the access road in relation to ongoing aggradation at the site and the associated flood risk.

The development of these options has been based on the principles of process-based restoration. This 'nature-based' approach aims to work with geomorphic processes as much as possible, within the constraints of the site and the needs of stakeholders. The options development process was guided by some high-level objectives, as set out in the original project brief and during a stakeholder meeting that was undertaken on site at the time of the fluvial audit. These objectives include:

- improve natural physical processes;
- improve biodiversity, i.e. the capacity of the Slugain Burn to support a healthy and diverse ecosystem;
- reduce local flood risk (e.g. by improving conveyance at the bridge crossing and providing additional floodplain storage elsewhere);
- improve climate change resilience;
- benefit estate and farm activity, including access and maintenance (e.g. by improving the existing bridge crossing);
- retain/enhance access for recreational users (e.g. by improving bridge crossing);
- raise awareness within the local community in Carrbridge of the many benefits of river restoration, including demonstration of achieving balance between land use and natural river processes.

At present, there are considerable artificial constraints to natural fluvial form and process (i.e. extensive embankments, channel straightening) in the lower parts of the Slugain Burn and a number of impacts related to these constraints (e.g. channel aggradation, reduced conveyance through the bridge). Accordingly, the options presented here seek primarily to remove these artificial constraints and reinvigorate dynamic river processes; this can be achieved to varying degrees depending on the preferred option.

It is recognised that there are a number of other physical and ecological constraints at this site, including the access road (and associated bridge), surrounding land use and the ecological value of the existing drainage network, particularly for wading birds. Therefore, although the greatest long-term benefits (in terms of natural form/function and reduced ongoing maintenance requirements) can be achieved by restoring the Slugain Burn to its 'reference state', the proposed restoration options aim to restore natural conditions as far as is practicable given the constraints. The current Slugain Burn has been simplified and degraded considerably from its reference state, which is likely to have been a wandering or braided channel with extensive alluvial bar forms, with sediment supplied to an alluvial fan setting from the steeper, confined headwater reaches. Most of the options presented here will allow reinstatement of this dynamic river typology; therefore, although a fixed channel planform is indicated in the options maps, the overarching restoration approach is one of 'assisted recovery' where the river is effectively encouraged to 'do the work' of long-term restoration and physical/ecological evolution (albeit within the identified practical constraints identified across the site). This approach will reinvigorate natural dynamic channel behaviour and the development of a new quasi-stable equilibrium state over time, with all the associated ecological improvements. It is important to note that, for all of the proposed options, there are a range of potential interventions that could be adopted as part of the 'assisted recovery' approach, including (but not limited to) installation of in-channel large wood structures, gravel augmentation, bed raising/channel reprofiling and channel realignment. The degree of intervention required to fully reinvigorate natural dynamic channel behaviour should be constrained in more detail during the design phase for the preferred option, based on hydrodynamic and morphodynamic modelling. Accordingly, the options presented here should be considered a broad indication of the overarching features of the design rather than a prescriptive final design solution.

This section describes each option in turn with a brief summary, including associated benefits, disadvantages, potential risks and mitigation measures, based on the work presented in this report and a stakeholder consultation undertaken on 17th January 2023. Indicative maps are presented to illustrate the proposed measures; it is important to note that the locations and extents of any interventions should be considered only indicative at this stage. The criteria considered for appraisal of the options included:

- *Benefit to fluvial process and habitat.* The greatest benefit to fluvial process can be achieved by allowing the river to adjust to its natural form; restoration and management options in which the Slugain Burn will be closer to its 'reference' condition can be considered to offer greater benefits. The reinstatement of natural form and process will both improve physical and ecological diversity and have considerable effects on sediment transport, thus addressing the ongoing issues with aggradation at the site.
- *Wider environmental benefits (e.g. ecology/habitat)*. In addition to fundamental improvements to fluvial processes, the optioneering process has considered potential benefits to riparian and floodplain habitat (e.g. for fish, invertebrates and birds) and general improvements in ecosystem health and diversity, including potential disruption to existing good habitat.
- *Impact on flooding.* The potential for each of the proposed options to affect flood risk, both at the site and downstream, was considered.
- *Climate change resilience*. The optioneering process considered the potential for each option to enhance resilience to future climate change, i.e. the potential for the measures to 'buffer' extremes in flow. The appraisal also considered the potential of the measures to limit significant morphological adjustment in response to extreme flow events, thus reducing the risk of sudden shifts to a new morphological regime (which often occurs in association with significant local changes to sediment supply). In particular, better connection between the channel and the floodplain will enhance floodplain storage, making the system more resilient to both drought and flood, and the development of a more heterogeneous channel morphology will provide instream drought refugia.
- *Amenity value, land use and infrastructure.* This criterion considers the degree of protection of existing infrastructure/amenity (e.g. the importance of the area for hiking, dog-walking, etc) and the potential for additional amenity value. This is somewhat subjective: stakeholders

and landowners are likely to have different views regarding what constitutes 'value' in this context. Accordingly, both positive and negative influences were considered. This criterion also considers the potential effects of the options on ongoing land use and management.

- *Degree of disruption/disturbance required for construction.* Although construction is likely to create only short-term disruption, many of the proposed options will require some level of impact to surrounding infrastructure and agricultural land.
- *Cost and complexity of construction and 'buildability'.* The inclusion of this criterion allows consideration of approximate costs and highlights any specific practical issues with the proposed options that may increase the complexity and, therefore, risk of the construction.

Each option has been assigned a qualitative ranking for each of the criteria listed above. These are presented in an options assessment matrix in Table 4.1 to allow a qualitative comparison of the benefits and risks/disbenefits of each option.

Option 1	Do Nothing

Description

- Cease any regular channel management activities and do not undertake any further maintenance works
- Very occasional 'emergency' measures may still be permissible, under extreme circumstances

Advantages

- No direct associated costs
- No disruption to existing habitat
- No disruption to infrastructure and surrounding land use

Disadvantages

- No improvements in fluvial process and habitat
- No wider ecological benefits
- No improvements in flood risk and access – potential for further increase in flood risk upstream of bridge as deposition/aggradation continues
- No improvements in climate resilience
- No improvements in amenity value/infrastructure
- Potential for further degradation of river system
- Potential for future unpredictable failure of bridge and embankments

Risk appraisal and mitigation measures

n/a

Further assessments and permissions required

n/a

Option 2	Realignment to create new channel, using channel A and moving bridge ~30 m

Description

- Realign channel upstream of road along existing topographic low, using large wood structures to train flow through new road bridge ~30 m to east of existing bridge
- Remove embankments and use material to infill existing channel and ditch along road, retaining coarse alluvial sediment for use in new channel
- Excavate new channel across floodplain, tying into channel A downstream
- Naturalise channel A to initiate the recovery of natural geomorphic process and encourage a degree of lateral adjustment of channel to achieve more sinuous planform (considering local site constraints)
- Degree of intervention required to naturalise likely to be variable along length of channel/ditch, e.g. installation of large wood structures, reprofiling of banks to reconnect channel to floodplain, construction of two-stage channel
- Installation of large wood structures in newly constructed channel
- Excavation of scrapes and wetland habitat on floodplain
- Enhance existing woodland habitat towards downstream end of channel A

Advantages

- Considerable **benefit to fluvial process and in-stream habitat** through channel realignment and naturalisation, including considerable increase in channel length and reinstatement of more natural form and process
- Wider environmental benefits through **improvements in riparian and floodplain habitat**
- Considerable **flood risk benefits** locally (through increased bridge conveyance) and possible minor benefits downstream (through enhanced floodplain storage during flood events)
- Enhanced **resilience to both flood and drought** through increased floodplain storage and increased morphological heterogeneity in active river corridor
- Replacement of bridge with more suitable structure, reducing risk of future flooding/washing out of **access road**
- Reduced risk of infrastructure failure via replacement of bridge crossing and removal of embankments, **reducing ongoing maintenance requirement**
- **Potential for improved amenity value** to be incorporated into design (e.g. footpaths)
- **Limited cut** required upstream of road owing to use of existing topographic low

Disadvantages

- **Costs** associated with cut volume required to excavate new channel (~1800 m^3)
- **Disruption** to access road, car park and grazing land during construction
- **Land take** required to realign channel – construction of channel across floodplain likely to **impact land management** considerably
- Construction of channel across floodplain likely to **reduce grazing** on floodplain – grazing is required to support **existing good wader habitat** at the site
- Achieving appropriate bridge capacity at this location may require raising of road/creation of **road embankment,** resulting in **more costly construction** relative to other options

Risk appraisal and mitigation measures

- *Potential for lateral migration of channel upstream of new bridge taking channel course away from bridge opening*: Moderate risk, mitigated by design (i.e. use of training logs, construction of symmetrical plane bed channel)
- *Potential for ongoing deposition of sediment upstream of new bridge*: Moderate risk, mitigated by careful design of bridge geometry and reinstatement of more natural sediment dynamics

• *Risk of avulsion of mainstem Dulnain into restored channel during flood events, resulting in loss of restored channel length*: Moderate risk (i.e. similar to existing conditions), can be constrained based on morphodynamic modelling • *Risk of large wood mobilising during high flows*: Low risk, minimised through careful design and construction • *Risk of head cut/instability at tie-in points*: Moderate risk, can be mitigated by careful design using modelling
Further assessments and permissions required topographic survey, hydrodynamic/morphodynamic modelling, detailed design, consideration of regulatory requirements, consultation, utilities surveys, ecological assessment

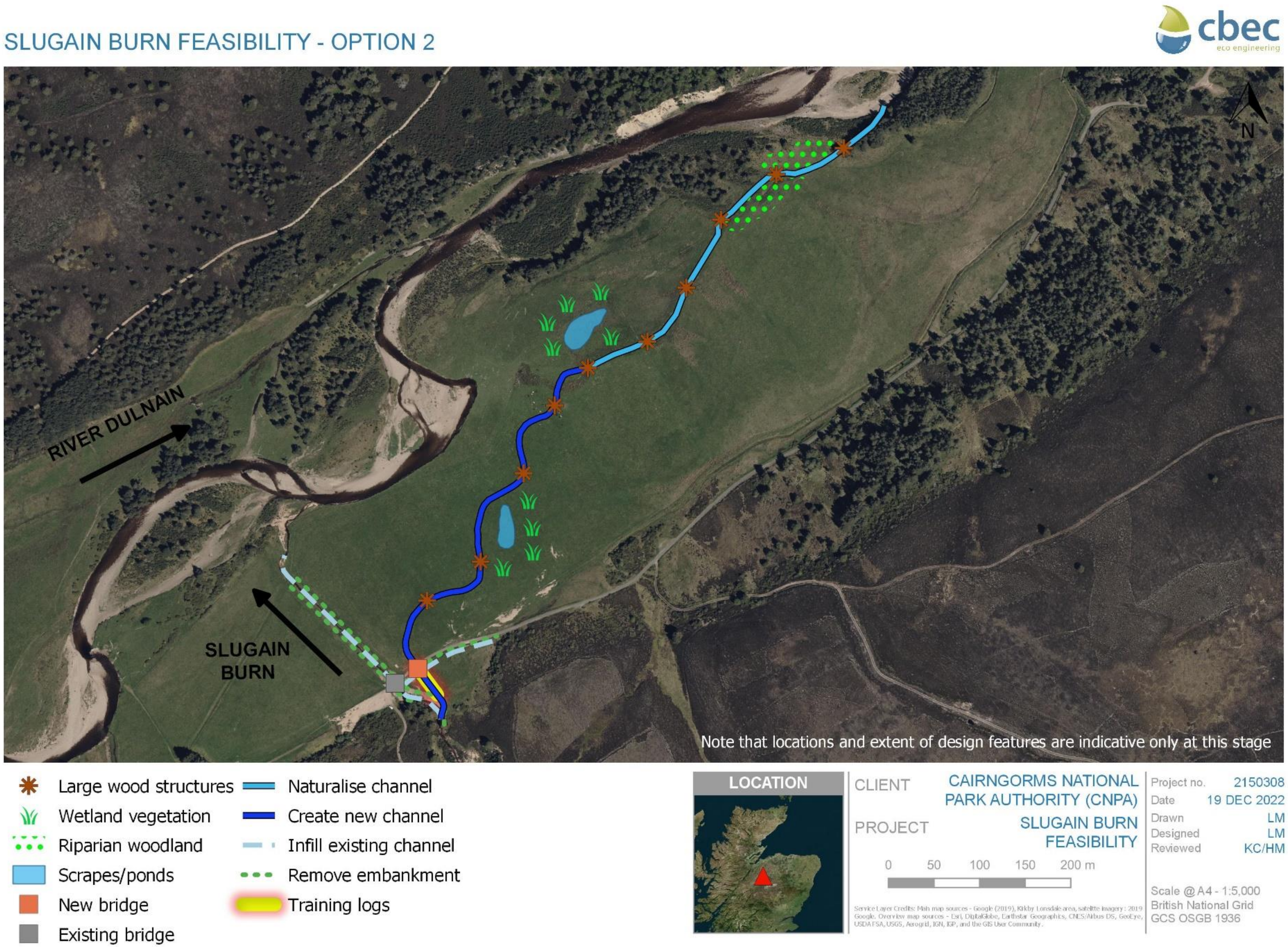

Figure 4.1. Option 2 overview map.

Option 3	Realignment to create new channel, using channel A and moving bridge ~100 m

Description

- Realign channel upstream of road by excavating through raised ground, using large wood structures to train flow through new road bridge ~100 m to east of existing bridge
- Remove embankments and use material to infill existing channel and ditch along road, retaining coarse alluvial material for use in new channel
- Excavate new channel across floodplain, tying into channel A downstream
- Naturalise channel A to initiate the recovery of natural geomorphic process and encourage a degree of lateral adjustment of channel to achieve more sinuous planform (considering local site constraints)
- Degree of intervention required to naturalise likely to be variable along length of channel/ditch, e.g. installation of large wood structures, reprofiling of banks to reconnect channel to floodplain, construction of two-stage channel
- Installation of large wood structures in newly constructed channel
- Excavation of scrapes and wetland habitat on floodplain
- Enhance existing woodland habitat towards downstream end of channel A

Advantages

- Considerable **benefit to fluvial process and in-stream habitat** through channel realignment and naturalisation, including considerable increase in channel length and reinstatement of more natural form and process
- Wider environmental benefits through **improvements in riparian and floodplain habitat**
- Considerable **flood risk benefits** locally (through increased bridge conveyance) and possible minor benefits downstream (through enhanced floodplain storage during flood events)
- Enhanced **resilience to both flood and drought** through increased floodplain storage and increased morphological heterogeneity in active river corridor
- Replacement of bridge with more suitable structure, reducing risk of future flooding/washing out of **access road**
- Reduced risk of infrastructure failure via replacement of bridge crossing and removal of embankments, **reducing ongoing maintenance requirement**
- **Potential for improved amenity value** to be incorporated into design (e.g. footpaths)
- Location of new bridge takes advantage of existing road levels, **reducing costs considerably** (relative to Option 2)

Disadvantages

- **Costs** associated with cut volume required to excavate new channel (~2500 m^3)
- **Disruption** to access road, car park and grazing land during construction
- **Land take** required to realign channel – construction of channel across floodplain likely to **impact land management** considerably
- Construction of channel across floodplain likely to **reduce grazing** on floodplain – grazing is required to support **existing good wader habitat** at the site
- **Additional cut** required upstream of road bridge to achieve realignment (relative to Option 2)

Risk appraisal and mitigation measures

- *Potential for lateral migration of channel upstream of new bridge taking channel course away from bridge opening*: Moderate risk, mitigated by design (i.e. use of training logs, construction of symmetrical plane bed channel)
- *Potential for ongoing deposition of sediment upstream of new bridge*: Moderate risk, mitigated by careful design of bridge geometry and reinstatement of more natural sediment dynamics

• *Risk of avulsion of mainstem Dulnain into restored channel during flood events, resulting in loss of restored channel length*: Moderate risk (i.e. similar to existing conditions), can be constrained based on morphodynamic modelling • *Risk of large wood mobilising during high flows*: Low risk, minimised through careful design and construction • *Risk of head cut/instability at tie-in points*: Moderate risk, can be mitigated by careful design using modelling
Further assessments and permissions required topographic survey, hydrodynamic/morphodynamic modelling, detailed design, consideration of regulatory requirements, consultation, utilities surveys, ecological assessment

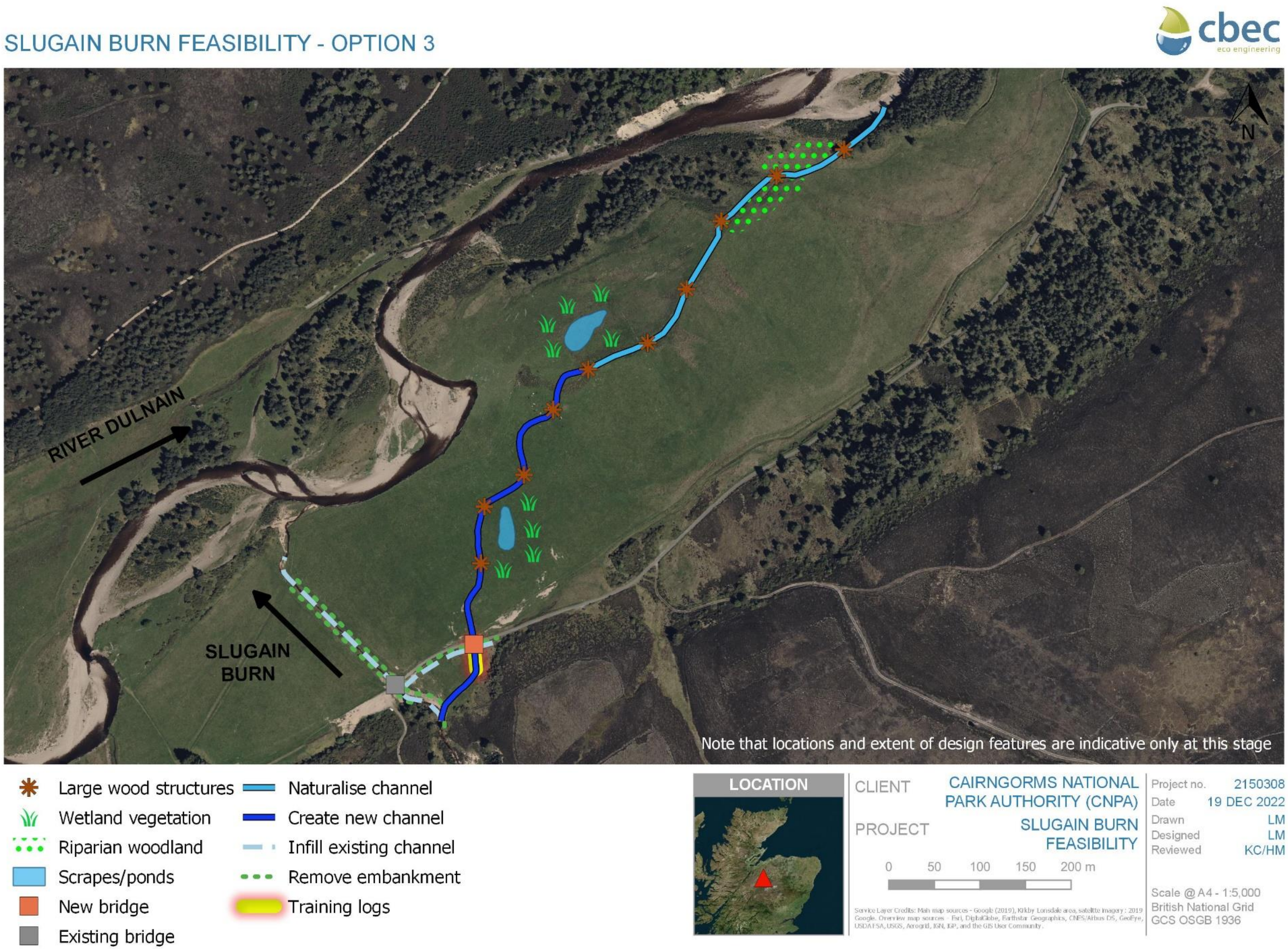

Figure 4.2. Option 3 overview map.

Option 4	Realignment to create new channel, using channel B and moving bridge ~100 m

Description

- Realign channel upstream of road by excavating through raised ground, using large wood structures to train flow through new road bridge ~100 m to east of existing bridge
- Remove embankments and use material to infill existing channel and ditch along road, retaining coarse alluvial material for use in new channel
- Excavate new channel across floodplain (potentially following alignment of flow during previous avulsion event), tying into channel B downstream
- Naturalise channel B to initiate the recovery of natural geomorphic process and encourage lateral adjustment of channel to achieve more sinuous planform (considering local site constraints)
- Degree of intervention required to naturalise likely to be variable along length of channel/ditch, e.g. installation of large wood structures, embankment removal, reprofiling of banks to reconnect to channel to floodplain, construction of two-stage channel
- Installation of large wood structures in newly constructed channel
- Excavation of scrapes and wetland habitat on floodplain
- Enhance existing woodland habitat towards downstream end of channel B

Advantages

- Considerable **benefit to fluvial process and in-stream habitat** through channel realignment and naturalisation, including considerable increase in channel length and reinstatement of more natural form and process
- Wider environmental benefits through **improvements in riparian and floodplain habitat**
- Considerable **flood risk benefits** locally (through increased bridge conveyance) and potential minor benefits downstream (through enhanced floodplain storage during flood events)
- Enhanced **resilience to both flood and drought** through increased floodplain storage and increased morphological heterogeneity in active river corridor
- Replacement of bridge with more suitable structure, reducing risk of future flooding/washing out of **access road**
- Reduced risk of infrastructure failure via replacement of bridge crossing and removal of embankments, **reducing ongoing maintenance requirement**
- **Potential for improved amenity value** to be incorporated into design (e.g. footpaths)
- Location of new bridge takes advantage of existing road levels, **reducing costs considerably** (relative to Option 2)
- **Land take** required to realign channel, but **closer to field margins** relative to Options 2 and 3 and less likely to impact on ongoing land management
- **Limited disruption** to wider floodplain area during construction
- **Retention of grazing land** across most of floodplain, offering benefits for both land use and **wader habitat**

Disadvantages

- **Costs** associated with cut volume required to excavate new channel (~1700 m^3) and remove embankment associated with channel (~320 m^3)
- **Disruption** to access road, car park and grazing land during construction
- **Additional cut** required upstream of road bridge to achieve realignment (relative to Option 2)
- Potential **future risk to road** from lateral adjustment of restored channel

Risk appraisal and mitigation measures

- *Potential for lateral migration of channel upstream of new bridge taking channel course away from bridge opening*: Moderate risk, mitigated by design (i.e. use of training logs, construction of symmetrical plane bed channel)
- *Potential for lateral adjustment of channel downstream of bridge affecting access road*: Moderate, can be constrained based on morphodynamic modelling and risk mitigated in design
- *Potential for ongoing deposition of sediment upstream of new bridge*: Moderate risk, mitigated by careful design of bridge geometry and reinstatement of more natural sediment dynamics downstream of bridge
- *Risk of avulsion of mainstem Dulnain into restored channel during flood events, resulting in loss of newly constructed channel*: Low risk owing to distance between mainstem and new channel, can be constrained based on morphodynamic modelling
- *Risk of large wood mobilising during high flows*: Low risk, minimised through careful design and construction
- *Risk of head cut/instability at tie-in points*: Moderate risk, can be mitigated by careful design using modelling

Further assessments and permissions required

topographic survey, hydrodynamic/morphodynamic modelling, detailed design, consideration of regulatory requirements, consultation, utilities surveys, ecological assessment

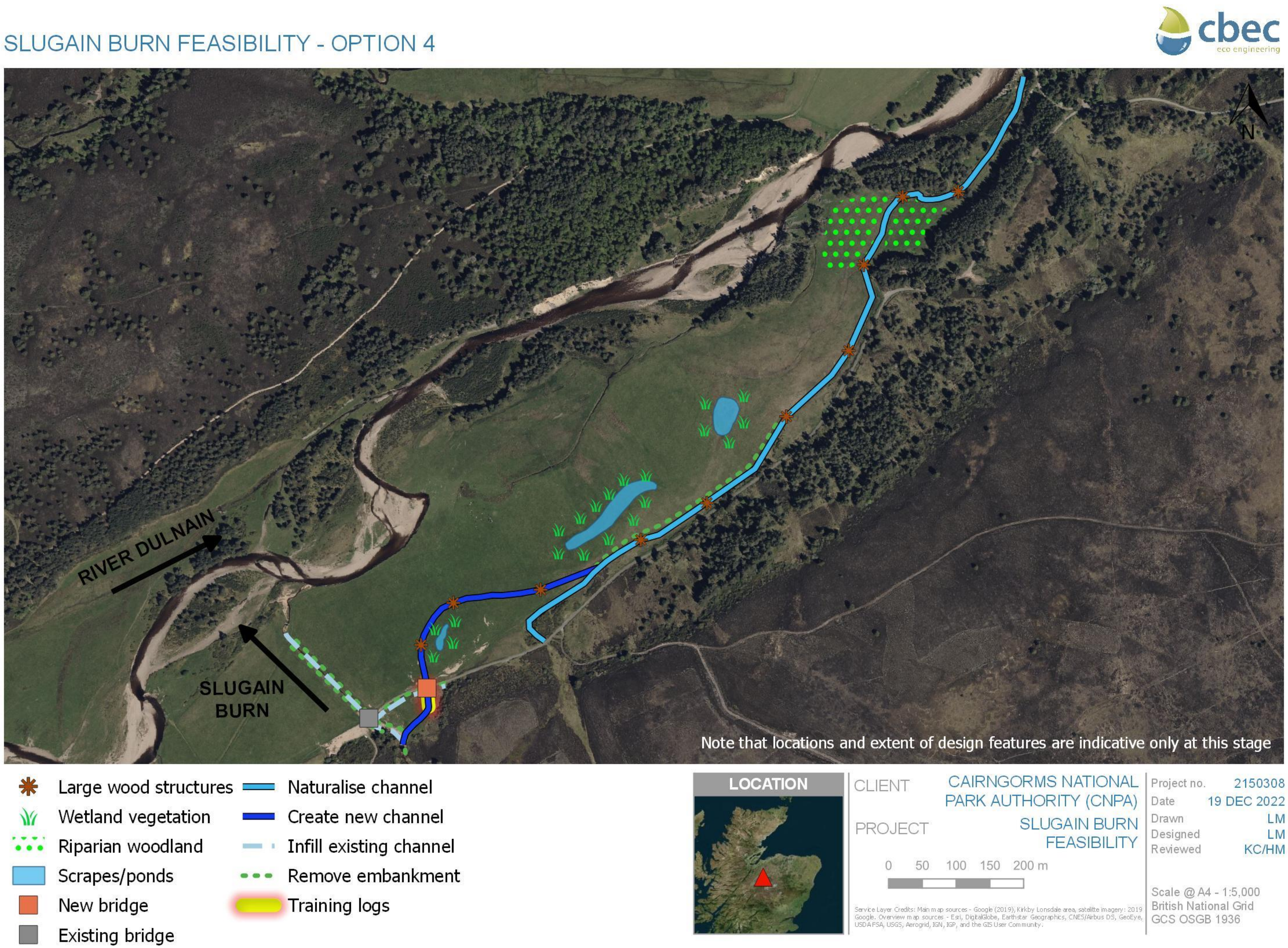

Figure 4.3. Option 4 overview map.

Table 4.1. Options appraisal matrix – Slugain Burn.

Factor	Option 1 (Do nothing)	Option 2 (use channel A and move bridge ~30 m)	Option 3 (use channel A and move bridge ~100 m)	Option 4 (use channel B and move bridge ~100 m)
Benefit to fluvial process and habitat				
Wider environmental benefits				
Impact on flooding				
Climate change resilience				
Amenity value, land use and infrastructure				
Degree of disruption/disturbance				
Cost/complexity of construction				

Significantly Positive; Slightly Positive; Neutral; Slightly Negative; Significantly Negative

4.2 CONSULTATION

Following development of the options, an online meeting was held with key stakeholders (including the land agent) on 17th January 2023. Following presentation of the different options by cbec to stakeholders, the benefits and disadvantages of the different options were discussed. There was general agreement between all stakeholders at the meeting that option 4 represented the most feasible option for the site whilst meeting specific stakeholder requirements relating to issues such as land management and protection of wader habitat. A number of other potential opportunities relating to Option 4 were identified as part of the stakeholder consultation and should be considered in more detail as the design progresses. In particular, the opportunity to naturalise and improve the confluence of channel B with the mainstem River Dulnain was discussed; the design should consider measures to improve flow and sediment connectivity and fish passage between this channel and the Dulnain and the potential to naturalise/replace the hard bank protection in place here. Other benefits highlighted for consideration in the design included relocation of redundant fencing lines, removal of an old sleeper bridge and the potential for regeneration of juniper following embankment removal. It was suggested that the existing channel could be used to create additional habitat (e.g. ponds); however, this would likely increase the risk of the newly constructed channel avulsing into the old channel course and would also reduce the volume of cut material that could be reused on site, resulting in increased costs during the construction phase.

A critical component of the options development and feasibility assessment for this restoration project is consideration of a new bridge to replace the current bridge, which is located just downstream of the point at which the Slugain Burn meets the floodplain of the Dulnain valley. Following agreement on option 4, further consultation took place between cbec, Moxon Architects and Highland Council to discuss high-level design requirements for the new bridge. It was agreed that the new bridge should have a considerably higher clearance than the existing bridge, making it more resilient to high flows and ensuring continuity of sediment transport. The replacement of the bridge with a more suitable structure should result in a significant reduction in the maintenance load by reducing the need for sediment removal and dredging. Additionally, the structure should minimise physical constraints to the burn, ensuring longitudinal connectivity and allowing space for the stream bed, whilst providing robust access to the upper glen for estate vehicles. Highland Council confirmed that the bridge span and soffit level must be designed to pass a 1:200 year (+climate change) flood and be sufficiently wide to support a 3000 mm carriageway and two 600 mm wide verges. Whilst the final bridge design will require outputs from the design modelling, it was agreed that the new channel would need to maintain a uniform gradient through the bridge and that the abutments should be set back from the channel, with construction costs for the abutments reduced by utilising the existing site topography to achieve the appropriate deck elevation if possible.

5. HIGH-LEVEL COST ESTIMATES

Indicative costs are provided for option 4 in Table 5.1, a more detailed breakdown is provided in Appendix A. These costs are based on a site visit by the specialist contractor and results of the cut/fill analysis. Upper and lower estimates have been provided to reflect the risks associated with the costing exercise. It should be noted that, at the feasibility and concept design stage of a project, there are still a significant number of unknowns relating to the final design; therefore, any cost estimates should be used with caution and the associated risks understood.

Table 5.1 Upper and lower level cost estimates.

Option	**Lower cost estimate (excl. VAT)**	**Upper cost estimate (excl. VAT)**
4	**£213,654.00**	**£235,019.40**

The indicative values provided above include costs for identified additional surveys or assessments (including high-level site investigation works), design, modelling and construction costs (including site supervision and setting-out). Costs have been included for an ECoW but not electrofishing. The budget makes allowance for the removal and disposal of the old bridge, but does not make allowance for constructing a new road to highways specification in the area where the bridge was. These costs are being provided by Moxon Architects. Costs have not been included for fencing or gates or for dealing with any invasive species, buried waste or contaminated land.

Costs are based on 2023 rates, are exclusive of VAT and do not include costs for any woodland or wetland planting or specialist ground preparation of the works site. Post-build monitoring and survey work costs have not been included; neither have costs for obtaining any required consents and permissions. Site supervision has been costed on the basis of construction taking 6 weeks, with a one-day site visit per week.

Construction costs assume the following:-

- Large wood would be supplied free issue to the contractor and delivered to the project site.
- All excavated material not being used to fill the existing channel will be landscaped locally, i.e. within 20 m of where it was excavated. No allowance has been made for the removal of material off site.
- Material for the bed of the new channel can be won through riddling the excavated material; costs have not been included for importing any material to site to form the bed of the new channel.
- There are no buried services requiring specialist protection measures and no protection measures are required for overhead power lines.
- The works would be undertaken in the summer months, and the budget is based on 2023 rates.

6. CONCLUSIONS AND NEXT STEPS

Following the options appraisal process and the stakeholder consultation undertaken on 17th January 2023, it has been determined that Option 4 is the preferred option for restoration of the Slugain Burn for the following reasons:

- reduced cost for bridge construction (relative to Option 2) owing to potential to utilise existing road levels;
- reduced impacts on wider floodplain (relative to Options 2 and 3) during construction;
- reduced land take across floodplain (relative to Options 2 and 3), resulting in greater potential for ongoing use as grazing land and associated benefits for wader habitat;

- lower cut volumes estimated (relative to Option 3, which would follow the same alignment upstream of the road).

Based on the options development and feasibility assessment and general agreement of all stakeholders that Option 4 represents the most feasible option for the site, it is recommended that this option now be taken forward to detailed design phase and the required topographic survey and hydraulic modelling undertaken to inform the design. Any additional surveys that may be required prior to the design phase (e.g. ground investigation, baseline ecological surveys) should be prioritised in the meantime.

7. REFERENCES

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APPENDIX A

High Level Cost Estimate Breakdown

Slugain Burn Restoration Project - High Level Cost Estimates (excluding new bridge)

STAFF LABOUR COSTS	
Project Initiation Meeting	£300.00
Ground Investigation Works	£6,000.00
Construction	£180,000.00
Field Surveys	£5,260.00
Design Options	£1,600.00
Detailed Design	£6,660.00
Draft Report	£3,410.00
Final Report	£730.00
Construction supervision	£3,120.00
Site setting out	£2,232.00
As built survey	£1,872.00
Total	£211,184.00

REIMBURSABLE EXPENSES	
Project Initiation Meeting	£0.00
Ground Investigation Works	£0.00
Construction	£0.00
Field Surveys	£0.00
Design Options	£0.00
Detailed Design	£0.00
Draft Report	£0.00
Final Report	£0.00
Construction supervision	£960.00
Site setting out	£825.00
As built survey	£685.00
Total	£2,470.00

PROJECT BUDGET SUMMARY	
Reimbursable expenses	£2,470.00
Total staff labour costs	£211,184.00
Total sub-contractor fees and expenses	£0.00
VAT (on labour, reimbursables & sub-contractor costs)	£42,236.80
TOTAL ESTIMATED BUDGET (excluding VAT)	**£213,654.00**
TOTAL ESTIMATED BUDGET (including VAT)	**£255,890.80**

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