Earba Pumped Hydro Scheme
Hydromorphological Appraisal Rev B

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1 INTRODUCTION

1.1 Terms of Reference

EnviroCentre Ltd were commissioned by Gilkes Energy Ltd, on behalf of Earba Ltd, to undertake a hydromorphological appraisal in relation to the proposed Earba Pumped Storage Hydropower Scheme (PSH) on Ardverikie Estate, Kinloch Laggan. This hydromorphological assessment is required to support the Planning and Controlled Activities Regulations (CAR) applications for the development, following consultation with the Scottish Environment Protection Agency (SEPA). The report will be included as a Technical Appendix to the Environmental Impact Assessment Report.

Revision A of this report was produced following consultation with SEPA and extended the key study areas to include the Moy Burn and Loch Earba. The current version of the report, Revision B, reflects refined designs for the Pitridh Aqueduct, the Moy Burn compensatory channel habitat and the Leamhain Outfall arrangements, following further collaboration with SEPA.

1.2 Scope of Report

The proposed PSH development would operate by transferring water between two existing loch systems, the capacity of which would be enhanced through the formation of dams. The lower reservoir would be formed at Loch Earba (*Lochan na h-Earba*) and the upper reservoir would be formed at Loch Leamhain (*Loch a' Bhealaich Leamhain*).

The scope of the work is to assess the impact of the proposed PSH on the hydromorphology of Loch Earba and five key watercourse systems, which have been identified for assessment through SEPA consultation:

- Pitridh Burn (*Allt Coire Pitridh*);
- Chlachair Burn (*Allt Coire a' Chlachair*);
- Moy Burn;
- Allt Labrach;
- Leamhain Outfall (*Allt Loch a' Bhealaich Leamhain*).

The impacts to the physical processes will be assessed in relation to proposed Pitridh Aqueduct (which will divert the lower reaches of the Pitridh and Chlachair Burns), downstream inundation effects (Moy Burn), and upstream impoundment (Allt Labrach and Leamhain Outfall). The impact of the scheme on sediment transport processes through Loch Earba will also be appraised.

The study watercourses were initially characterised through review of background information, site walkover and spatial analysis, in order to assess the current hydromorphological condition and identify dominant processes and channel typologies present. This understanding then underpinned a qualitative appraisal of the potential impact of proposed impoundments, channel diversions and associated engineering on hydromorphology at a local and waterbody / catchment scale. Both short and long term impacts were considered. Outline recommendations have been made for potential mitigation measures to minimise or offset any negative impacts in terms of hydromorphological processes (e.g. modification of proposed features, operational maintenance).

The assessments have been undertaken on a qualitative basis using the information available, and have not extended to include topographic survey, sediment sampling, fluvial audit, sediment modelling or sediment budgeting.

The impact assessment focuses on the likely effects of the proposed diversions and impoundments on hydromorphology primarily through the impact on sediment transport processes. Consideration has also been given to the reduced flows in the depleted reaches during the operational phase; however sediment transport and 'channel-forming' processes predominantly occur during high flow conditions, when the relative reduction in flows due to hydropower operation would be very low or negligible.

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2 SITE CHARACTERISATION

2.1 Site Location

Loch Earba is located to the southeast of Loch Laggan, between Spean Bridge and Laggan. The development site and study watercourses (as defined by SEPA consultation) are shown on Figure 2-1. Loch Earba is formed by two lochs of the same name, separated by a short reach of channel and floodplain named *Am Magh (translated as 'The Plain')*.

Figure 2-1: Proposed development site and study watercourses

Loch Earba discharges to Loch Laggan; and to the Rivers Spean and Lochy beyond. Loch Leamhain sits within a neighbouring sub-catchment, which also discharges into Loch Laggan, via the Allt Cam and River Pattack (Figure 2.2).

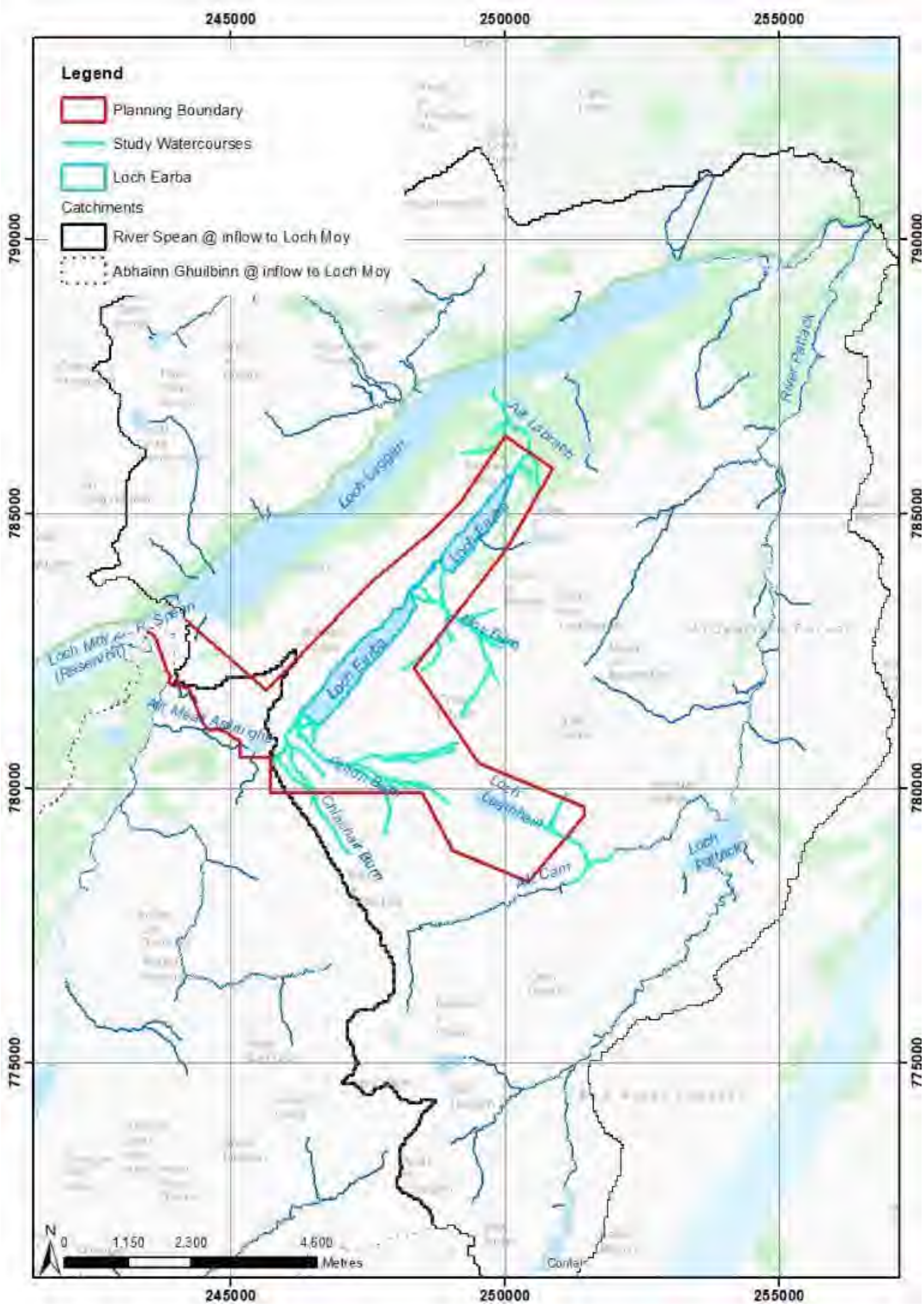


Figure 2-2: Wider catchment context

2.2 Proposed Development

The proposed generating capacity of the Earba PSH is up to 1,800 MW. The scheme would involve the use of new dams, to create reservoirs from existing lochs. There would be an upper reservoir on Loch Leamhain and a lower reservoir on Loch Earba. Key design drawings are provided in Appendices B to F.

For the smaller Loch Leamhain, a single rockfill dam would be constructed below the outflow of loch, creating an upper reservoir capable of storing approximately 55 million cubic metres of water and raising the level of the loch from its existing level of 640m AOD to a maximum level of 710m AOD (resulting in a drawdown range of 70m).

Catchwater / cut-off ditches are proposed within the Loch Leamhain catchment to isolate the upper Leamhain reservoir from the natural catchment run off, allowing half of the Leamhain catchment to feed directly downstream into the Leamhain Outfall (Allt a Bhealaich Leamhain) and Allt Cam. This is in place of a compensation flow discharge at the Leamhain Dam, in order to avoid the transfer of water from the Earba catchment into the Pattack catchment via the PSH scheme, to mitigate against the transfer of Invasive Non-Native Species (INNS).

Loch Earba is currently used as a storage reservoir for the existing Ardverikie Hydro Scheme (1MW), which discharges into Loch Laggan via the Allt Labrach. Loch Earba has two existing concrete dams which allow approximately 2m of drawdown in the existing lochs. The current schemes dams would be replaced by the proposed scheme but it is intended that the remaining infrastructure would remain so generation can continue. Earth / rockfill embankment dams would be constructed at each end of Loch Earba (Shios Dam to the east and Shuas Dam to the west) to create a lower reservoir with capacity to store approximately 65 million cubic metres of water. This would raise the level of the loch, from its existing top water level of 352m AOD to a maximum level of 376m AOD. Minimum inundation levels would be 355 mAOD, resulting in a drawdown range of 21m).

The upper and lower reservoirs would be connected by a tunnel system, including a surge shaft on the west ridge of Creag Pitridh. A powerhouse would be constructed on the southeast bank of Loch Earba. Associated infrastructure, including compounds, access routes, surge shafts and pipelines are shown in the outline arrangement plan in Appendix A.

In order to facilitate dam formation and operation, a diversion channel, to be known as the Pitridh Aqueduct, is required to intercept several tributaries and divert flows directly into Loch Earba at its upstream (west) end. This is to avoid ponding on the upstream side of the Shuas dam. A buried aqueduct is also planned, which would function to drain residual water from the area to the west of the Shuas Dam into the existing Allt Meall Ardruighe Reservoir further to the west. This reservoir is at the head of the Allt Meall Ardruighe watercourse, which discharges through the Abhainn Ghuilbinn and into Loch Moy (reservoir). Loch Moy is a short distance downstream of the Loch Laggan outlet, with a reach of the River Spean in between. It is understood that the Allt Meall Ardruighe Reservoir is operated by Ardverikie Estate (Controlled Reservoir Reference RES/R/1128065) for amenity purposes.

2.3 Site Walkovers

An initial site walkover was undertaken on 5th October 2023, accompanied by a senior project engineer from Gilkes Energy Ltd. The weather on the day was mostly dry with showers, following on from heavy rain in the preceding days. Flows in the channels were moderate and were observed to recede slightly over the course of the day.

A second walkover, with a focus on the Moy Burn and Loch Earba, was undertaken on 13th February 2024, accompanied by the same engineer. A thin layer of snow was present over the ground, although channel features were still sufficiently visible.

Access to most of the study watercourses was possible, although accessibility along the Allt Labrach was more limited due to dense woodland and steep slopes and so this channel corridor was mostly observed via several road crossings along its length. Channel and wider catchment conditions were visually assessed with a view to understanding dominant hydromorphological processes and sensitivities, with geo-tagged photos taken to record representative conditions and significant features.

Representative photos from the site walkovers are given in Appendix A.

2.4 Catchment Geomorphology and Geology

The landscape of the development site has been formed by glacial activity. Loch Earba is set within a U-shaped valley characterised by steep sides with rocky outcrops and a relatively flat valley floor where the lochs have formed. Alluvial fans are regularly present where watercourses break out onto the valley floor and deposit coarse sediment load. Loch Leamhain has formed in a corrie with steep scree slopes, particularly on the north side, and its outlet channel flows through an area of blanket bog.

British Geological Survey (BGS) Geology Viewer[1] was used to characterise the bedrock and superficial geology of the catchment. Bedrock is predominantly metamorphic throughout the study area, and is exposed in numerous valley side locations, and also within certain reaches of the study watercourses, where it exerts bed level control.

The bedrock underlying the Pitridh and Chlachair systems is mostly psammite, with granite to the north and bands of semipelite in the upper catchments. Superficial deposits of glacial till (diamicton) are present in the upper catchment, with alluvial fan deposits of gravel, sand, silt and clay where the tributary channels meet the valley floor. Towards the entrance to the loch the channels flow through alluvium comprised of clay, silt, sand and gravel. Peat deposits are also present, particularly through the lower reaches of the Chlachair Burn.

The Moy Burn is underlain by predominantly psammite and semipelite bedrock, with an area of igneous intrusion (granite) in the upper catchment and pockets of pegmatite in the lower catchment. Superficial deposits of glacial till (diamicton) extend through most of the Moy catchment, and at the head of the catchment deposits of gravel, sand, silt and clay are present. At the downstream end of the catchment, significant alluvial fan deposits have contributed to the formation of the Am Magh area separating the lochs (gravel, sand, silt and clay). Narrow deposits of alluvium (clay, silt, sand, gravel) are mapped along the channel corridor of the Moy Burn and the Am Magh channel.

The shores and bed of Loch Earba are mostly underlain by psammite and semipelite, with igneous instrusions on the flanks of Binnean Shuas (pegmatite) and on Creag Pitridh (granite and pegmatite), as well as a smaller intrusion of pegmatite to the southeast of the outlet on the lower loch. Superficial deposits around the loch are predominantly glacial till, with hummocky features particularly to the west of Am Magh (diamiction, gravel, sand and silt) and small pockets of peat. A smaller alluvial fan has formed at the outlet of the Coire Chuir outfall, to the east of the Moy Burn.

The bedrock along the corridor of the Allt Labrach is dominated by psammite (micaceous), with minor igneous intrusions. Hummocky glacial deposits of diamicton, gravel, sand and silt overly this bedrock, and pockets of alluvium are present along the river corridor (clay, silt, sand and gravel).

[1] https://www.bgs.ac.uk/map-viewers/bgs-geology-viewer/

The bedrock around Loch Leamhain and its outfall consists primarily of bands of semipelite, gneissose psammite and quartzite. Superficial deposits of glacial till (diamicton) are present in the upper reaches, while the lower reaches of the system flow through hummocky glacial deposits of diamicton, gravel, sand and silt. Alluvial deposits of clay, silt, sand and gravel are present on the approach to the Allt Cam confluence.

2.5 Waterbody Overview

2.5.1 Pitridh and Chlachair Burns

The Pitridh and Chlachair Burns (proposed for diversion by the Pitridh Aqueduct) rise as very steep channels from a ridge at approximately 1,000 mAOD to the southeast, and discharge into Loch Earba at around 360 mAOD. Their catchment areas are 4.8km^2 and 2.8km^2, respectively. They both have multiple small tributaries, some of which have short reaches that are multi-threaded or show signs of recent channel switching or avulsion as they flow down steep hillslopes and through hummocky glacial deposits. The main channels are for the most part relatively steep (with gorge / cascade sections) but there is a shallowing on the approach to the valley floor, where a substantial alluvial fan and relatively flat alluvial plain has formed, which is confined between the valley sides and the loch. Both channels meander through these alluvial deposits, which support peatland / wetland habitats, and confluence a short distance upstream of the loch.

Both of these high-energy watercourses are considered to be relatively natural, with no significant engineering or alterations observed, other than an access road crossing near the inflow to the loch and some localised historic bank modification at one location. The banks are vegetated by heath / grassland vegetation primarily, and are considered stable on the whole, with any bank erosion being localised in nature.

2.5.2 Moy Burn

The Moy Burn rises from several hills to the southeast and drains a catchment area of approximately 5.5km^2. The main channel and its tributaries are steep, high energy systems which mobilise large volumes of sediment, evident in the formation of the large alluvial fan deposit where the burn enters the loch at Am Magh, which has contributed to dividing the loch into its two parts. The stream power of the Moy Burn is high, as indicated by the predominance of large boulders along the length of the channel, with smaller clasts being readily transported out of the reach during spate, to be deposited on the alluvial fan or in the loch.

The lower reaches of the channel are split into three branches on Ordnance Survey maps. On the walkover survey the water was observed to flow along the southernmost branch, while the other two channels were dry. A review of historic maps indicated that the northern and central channels have been located at approximately these positions since at least the mid 1800's, although in geological timescales it is likely that the position of the channel(s) has migrated across the alluvial fan, adjusting around the sediments it is depositing. On the day of the walkover, stagnant water was observed within the central channel, presumably draining from the northern slopes and/or seepage from the current active channel which is contained behind an embankment. Under spate conditions it is considered likely that the dry channels would carry flows.

An embankment and other signs of realignment and engineering works were observed along the current active channel, for the purpose of fixing the position of the river through road crossings and to protect the hydro scheme structures in the loch beyond from sedimentation. This was confirmed by consultation with Ardverikie Estate, who commented that the Moy Burn was relocated further away from the middle dam because it was causing washouts and sediment deposits that compromised the integrity of the dam itself. In the late 1970s following a major storm the dam had to be rebuilt following a failure (approximately 18 months after original construction), and the burn was moved southwards as part of the dam rebuild.

2.5.3 Loch Earba

Loch Earba has formed at the base of a glacial valley. As noted above, it is supplied with sediments from a number of tributaries, many of which are associated with alluvial fan deposits which are present at the transition from steep upper slope to valley floor. The majority of sediment load, particularly the heavier clasts, will deposit out of suspension first in these areas. Finer materials will be transported further, to either deposit on the base of the loch or pass through the system in suspension.

The alluvial fan at Am Magh is likely to have contributed to the narrowing between the two parts of the loch, where flows pass through a short (1km) reach of channel between the upper and lower lochs. The channel is unnamed on maps but is referred to in SEPAs classification system as a separate waterbody called ‘Mid Lochan na h-Earba’. This channel has been modified in association with the hydro scheme, with realignment, re-profiling and sediment management evident for a few hundred metres downstream of the weir, at which outflows are actively controlled. Beyond this the channel takes a meandering form, with backwater channels present. Sediments are dominated by cobble and gravel in this reach.

Other than localised bank reinforcement along the road edge, the banks of the loch are predominantly in a natural condition and vegetated with long grasses, heath and pockets of woodland. Side slopes are typically shallow to moderate. No signs of significant instability are evident along the shoreline.

Bathymetric survey is not available, but sediment deposits are visible on aerial imagery (Figure 2-3), primarily at inlets / outlets, and narrow margins of the southeastern shore associated with tributary inputs. Within the loch, longshore drift will operate over longer timescales to shift shoreline sediments northeastwards, in line with the prevailing wind. This occurs as waves break obliquely on the shoreline, with swash moving material along the shore and then backwash, under gravity, pulls it back down at a right angle to the shoreline. Over the long-term this effect results in a net shift of substrate along the shoreline.

Figure 2-3: 2023 UAV aerial imagery of Loch Earba upper (left) and lower (right) reservoirs

2.5.4 Allt Labrach

The Allt Labrach is the outflow from Loch Earba, where the existing Ardverikie hydropower scheme modifies the hydrological regime through the system. The concrete dam structure is shown on Photo 7, Appendix A. This scheme was built a number of decades ago and it is understood that no formal requirement for compensation flows is in place. As such, flows through the channel are significantly lower than would be expected under typical natural conditions; although higher flows that would have more geomorphic influence will continue to spill over the dam structure. The watercourse is approximately 2km in length (falling from 350 to 250 mAOD) and at its discharge to Loch Laggan it drains a catchment of over 26 km^2.

Other than the upstream dam and several road crossings (with associated engineering being localised) there is little channel engineering or alteration evident, and the banks are naturally lined with dense woodland. The large boulder and cobbles dominating the substrate of the channel are indicative of a high energy / high stream power system, although a high proportion of the sediments show rounding and in-stream vegetation is present indicating stability. Since the installation of the hydropower scheme flows have been considerably reduced and attenuated at the lower end of the hydrological regime; although this effect will decrease as flows increase, meaning that stream power under channel forming conditions will remain relatively high. The substrates present in the channel in the current day are likely coarser / more armoured than would have naturally occurred, primarily reflecting impedance of sediment supply from upstream of the dam rather than a reduction in transport capacity.

2.5.5 Leamhain Outfall

The natural watercourse termed the ‘Leamhain Outfall’ spills from Loch Leamhain over a natural boulder control, and initially flows at a moderately steep slope through a narrow valley supporting blanket bog, before flowing more steeply down the side of the Allt Cam valley. On the approach to the valley floor the gradient of the channel is moderated for a short distance as it flows through glacial / alluvial fan deposits, before joining the Allt Cam. At this point the Leamhain Outfall drains a catchment area of approximately 4km^2.

The boulder / cobble-dominated substrates of the Leamhain Outfall include a significant proportion of rounded material, indicative of retention / stability. The banks are primarily lined by heath / grassland vegetation and there are no engineered structures or signs of significant alteration present. Localised erosion features are present, including exposed peat banks in the upper reaches, although these are considered natural and relatively minor in size when considered at a reach scale. This is a high energy system but overall the watercourse is considered stable and relatively balanced in terms of hydromorphological regime.

2.6 Waterbody Classifications

SEPA regulate river engineering in terms of impacts to hydromorphological quality elements, which in turn support ecological quality elements. The application will be determined with consideration of potential for deterioration of ecological status or potential, as well as potential alternatives and mitigating measures.

Waterbody Framework Directive (WFD) waterbody classifications were obtained from the SEPA Water Classification Hub[2]. The system falls within the Lochy catchment. The Allt Labrach (ID: 20369) is designated as a heavily modified water body (HMWB) on account of physical alterations that cannot be addressed without a significant impact on water storage for hydroelectricity generation. It is classified as having Bad Ecological Potential, owing to hydrology, hydromorphology and ecological factors. The Pitridh water body (ID: 20371) is categorised as having an overall status of Good, with hydrology and hydromorphology factors scoring High. The Chlachair Burn and Leamhain Outfall waterbodies are not classified.

The western (ID: 100204) and eastern (ID: 100200) waterbodies making up Loch Earba are both classified as HMWB, as above, and both have an overall classification of Good Ecological Potential. The western loch has a Moderate classification for hydromorphology while for the eastern loch the classification is Bad. The connecting channel between the lochs (‘Mid Lochan na h-Earba’; water body ID 20370) is classified as having a Good overall status, with Good status for both ecology and water quality. Its water flows and levels and physical condition are classified as High.

2.7 Channel Typologies

Channel typologies for the study watercourses have been characterised using the seven river types defined in *Supporting Guidance (WAT-SG-21) Environmental Standards for River Morphology* (SEPA, 2012). These types are listed in Table 2-1, in order of increasing sensitivity under typical conditions.

Table 2-1: River typologies (as per SEPA WAT-SG-21, Table 4)

SEPA River Type	Sub-Types
A	Bedrock, Cascade
B	Step-pool, Plane Bed
C	Plane-riffle, Braided, Wandering
D	Actively Meandering
E	Groundwater Dominated
F	Low Gradient Passively Meandering

River typologies are mapped in Figure 2-4. These have been generated through spatial analysis of digital terrain model data (LiDAR / Ordnance Survey Terrain 50) using ArcMap GIS software with 3D

[2] https://www.sepa.org.uk/data-visualisation/water-classification-hub/

Analyst extension. Channel slopes and sinuosity were derived and used to predict river typology following the thresholds set out in SEPA WAT-SG-21 guidance. Predominantly typologies A to C are present in the study watercourses, which is as expected in upland settings. The outcomes were verified by site walkover and review of UAV aerial imagery provided by the client.

The analysis confirms the findings of the site walkover, in that generally the study channels are high energy systems, with cascade and step-pool typologies dominating across the study watercourses. Occasional bedrock outcrops were noted particularly in the upper reaches of the Pitridh and Chlachair Burns and the Leamhain Outfall, and also along the Allt Labrach. On the site walkover, few sediment sources of significant size (e.g. slope failures) were noted along watercourses, and rather the sources are likely to be distributed throughout multiple tributaries / bankside contributions. Hummocky glacial deposits adjacent to channel banks are a local source of sediments in the lower reaches.

In terms of sediment deposition for the reaches identified as Type A or B, it was noted that small, localised accumulations of sediment were occasionally observed in marginal deadwater or in the lee of boulders, but few transient storage features of larger size (such as gravel/cobble bars) were observed indicating high transport capacity which may exceed potential rates of sediment supply.

These river types are associated primarily with transport processes, with little storage in the way of sediment bar features. Their regime is typified by ‘supply limited’ hydromorphic processes, where the transport capacity of the reach exceeds the rate of sediment supply. These river types are typically low in terms of sensitivity to physical change.

With reference to the Pitridh and Chlachair Burns, on the approach to the alluvial fan / alluvial plain at the base of the valley, the ratio between sediment supply and transport capacity decreases with decreasing slope, reflected in a transition in channel types through cascade, step-pool, plane bed and wandering morphologies (Type C). A moderately active sediment transport regime is indicated by the presence of multiple channels, eroding banks, cut-off meanders and within-channel storage of sediment bars. In-channel vegetation, vegetated banks and floodplain and sediment sorting are indicative of a relatively stable system over the short-medium term.

Although in-channel sediment deposition features (i.e. bars) through the alluvial fan area are frequently evident, it is considered likely that the annual sediment input rates from the upper catchments are low to moderate, and that these features largely represent re-working of sediments stored over the long-term. The deposits over the alluvial fan will act as a sediment sink, and sediments over the fan will be re-worked as the channel migrates dynamically over time. The loch will also act as a sink for suspended fine sediments as well as coarser bedload material.

Over the long term, the supply of sediment from multiple tributary sources upstream to the alluvial fan is potentially important in maintaining its integrity and morphology, as well as the morphology of the western end of the loch and the habitats associated with these features.

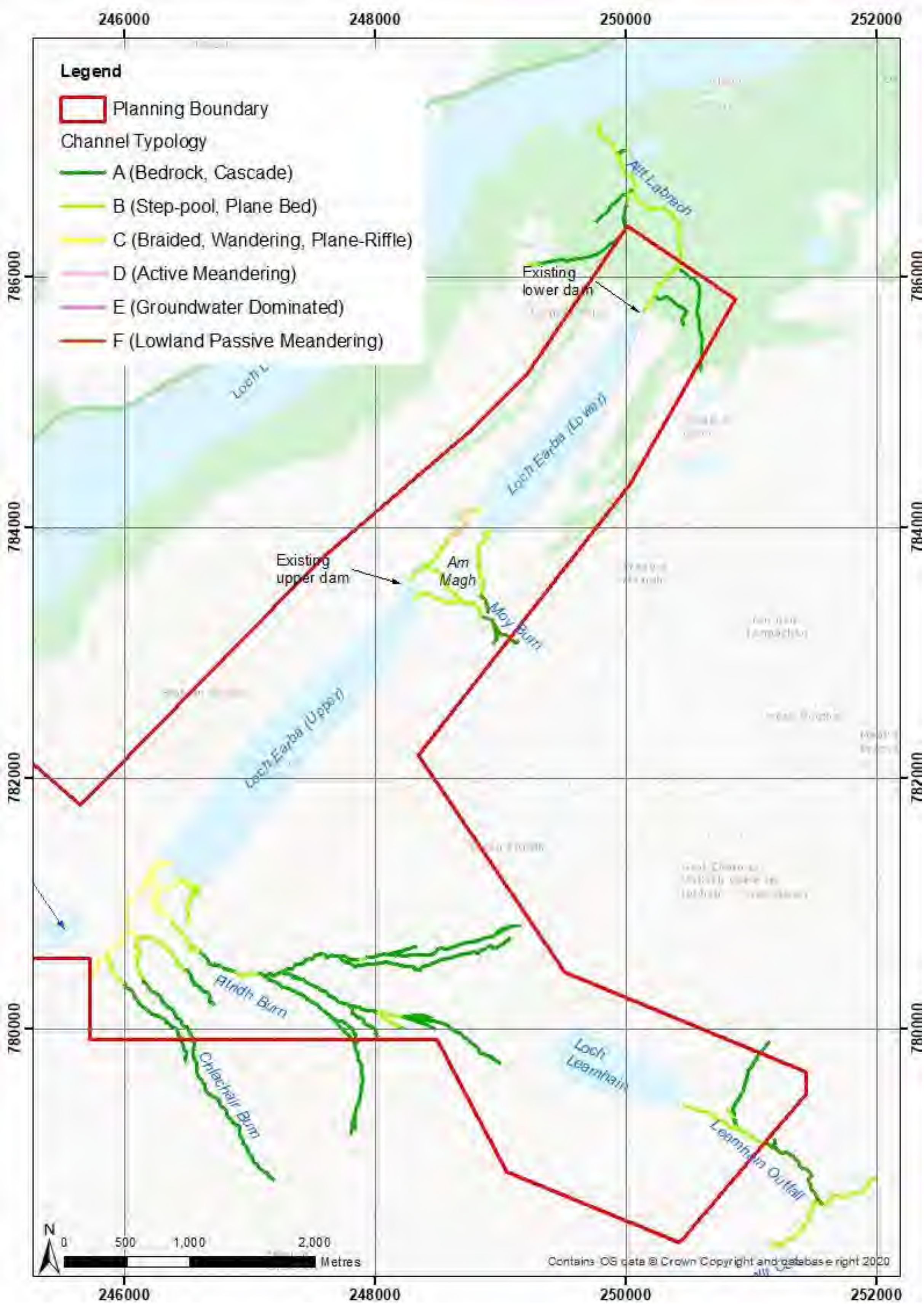


Figure 2-4: River typology

3 POTENTIAL IMPACTS

3.1 Nature of Potential Change

Potential impacts may be divided into construction and operational phases, with the latter being the main focus in the case of hydromorphological processes due to longevity of impact. The movement of coarse sediments through a channel is the primary driver of morphological process and form. Engineered impoundments and diversions, by their nature, disconnect upstream to downstream sediment flux. The reduction in supply and transport of coarse sediments downstream would impact on morphological processes and features over the long-term, which in turn may affect aquatic habitats. To a lesser degree, modification of the hydrological regime would also impact upon sediment transport processes, e.g. siltation / vegetation growth through prolonged periods of reduced flow and channel capacity adjustments following the reduced magnitude / frequency of higher 'channel-forming' flows in the channels affected by diversion.

Assessments of the abstraction regime and its implications on the frequency and magnitude of flood flows have been incorporated through the design process and the relative impact of the scheme on the downstream flood regime would diminish in line with rising return period. For more frequent channel forming flood events in particular (e.g. annual maximum or 1 in 2 year events), flood peaks would be attenuated to some degree downstream of impoundments. The beneficial influence of these floods on hydromorphological processes as well as habitats will be reproduced through freshet releases, where appropriate.

3.2 Impacted Reaches

The reaches impacted by the proposed PSH are predominantly downstream of the proposed dams and diversions and are shown on Figure 3-1. Mid- Lochan na h-Earba would effectively be drowned out, as it would be combined with the adjacent lochs to form one larger waterbody. The length of the study channels potentially affected by the proposed diversions and impoundments (subdivided by river type) are summarised in Table 3-1. It is important to note that the reaches closest to the proposed structures would be most impacted but that the impacts would be anticipated to diminish downstream (as flows and sediments are recruited from lateral sources) and would be physically limited in distance at the point of discharge into lochs.

Table 3-1: Reach lengths potentially impacted by altered sediment and flow regimes

Channel	Channel Length (m)				
	Typology				Total
	A	B	C	D	
Diversion: - mainstem Pitridh / Chlachair Burns	81	622	2133		**2,836**
- minor unclassified channels / tributaries	*172*	*4,086*	*620*		*2,095*
Mid Lochan na h-Earba		422		579	**1,001**
Moy Burn (downstream inundation, unclassified)		530			**530**
Allt Labrach	-	2,027	-		**2,027**
Leamhain Outfall	761	757	-		**1,518**

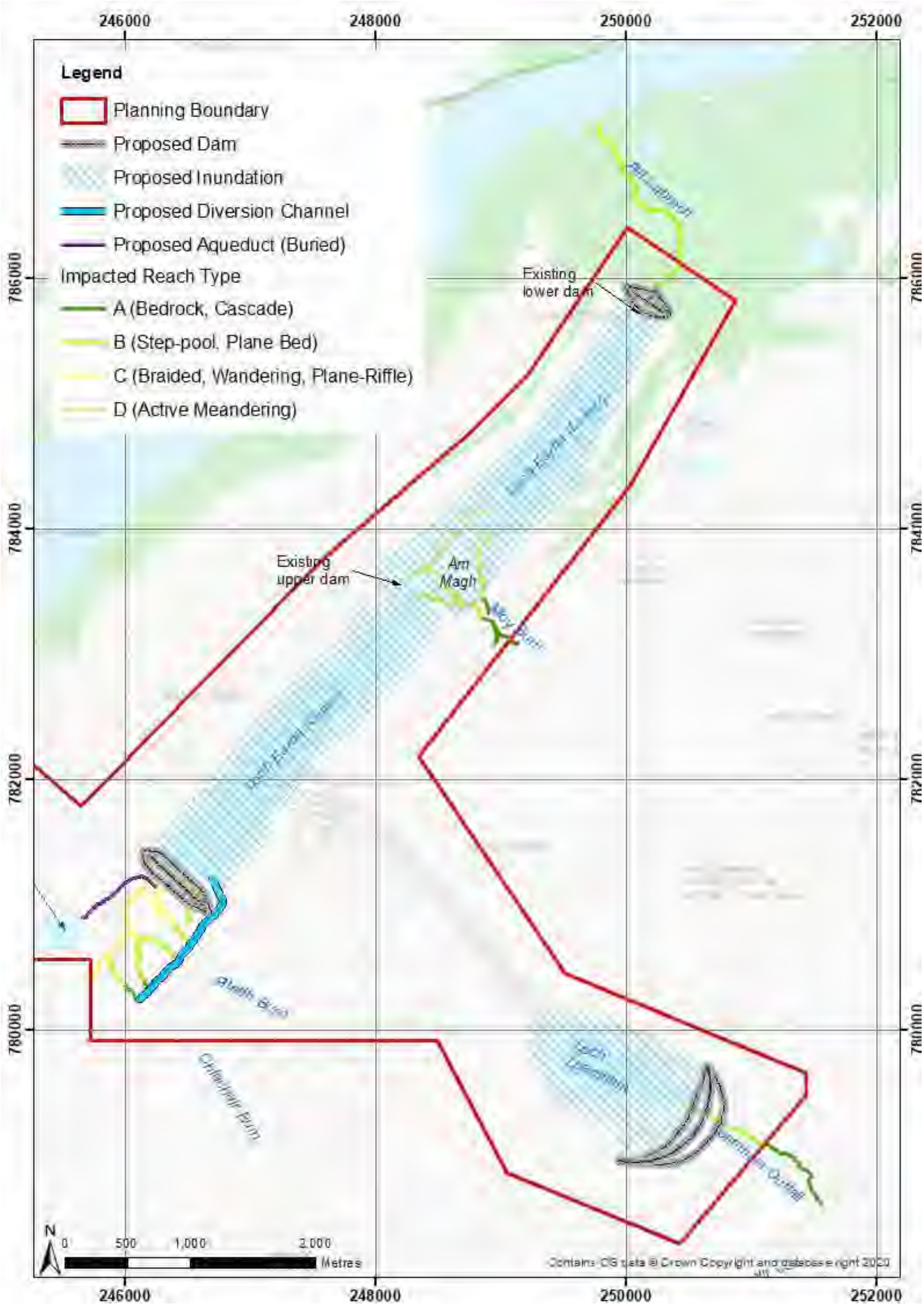


Figure 3-1: Potentially impacted reaches of study watercourses

3.3 Impoundments

The construction phase has the potential to impact morphology over the short-term (e.g. through physical disturbance to the channel and the release of sediments), although the significance of such impacts can be significantly mitigated, particularly through best practice in construction, and therefore are considered acceptable in the context of a high energy system with high background levels of disturbance during storm conditions.

Within Loch Earba and Loch Leamhain, the operation of the PSH will involve increased variability in loch levels. Water levels will fluctuate across a wider range of elevations and over a higher frequency than would naturally occur. The submergence of vegetation and physical movement of water over lochside vegetation will over time change its distribution and result in exposure of soil, peat and mineral substrates within the inundation zone. This will contribute to an increase in suspended and deposited material within the lochs over an initial adjustment period, although the effect will diminish over time. Given the scale of these waterbodies, which naturally act as sediment sinks, the effect will be limited and should not impact downstream reaches significantly above background levels of disturbance.

Over the operational phase one of the more significant long-term impacts of impoundment can be ‘sediment starvation’ in downstream channels, where sediment supply from the upstream catchment is reduced or prevented. This can lead to associated impacts such as an increased scouring of bed and banks, and a coarsening and/or armouring of substrate downstream. Habitats such as riffles and pools may be compromised, and increased scouring may cause damage to structures such as bridges; although scouring impacts would be less significant where larger, more resistant sediments dominate.

To assess the potential magnitude of impact, it is important to determine the relative rates of sediment supply: transport capacity ratio from upstream and downstream of the proposed dam location. In this case the relative impact is considered to be low, because the proposed dams are sited in the vicinity of existing, natural impoundments (enhanced for multiple decades in the case of the existing hydro scheme on Loch Earba), which limit the through-flow of sediments, particularly the coarser clasts. Most of the net sediment supply in the system currently is likely to originate from downstream of the proposed dam sites. The outfall channels are adjusted and stable in this context and so it is not anticipated that a significant destabilisation would be triggered following construction.

Any outflows from the proposed dams, designed to return water to the channel downstream, may pose a risk of localised scouring and channel destabilisation if the flow of water differs from the natural range experienced in the receiving channel, for example due to increased velocities and erosive capacity, requiring careful design and construction, and consideration in freshet planning.

Overall, the operational phase of the scheme would be considered to have a limited effect on sediment transport processes, and therefore, channel morphology. The impact would diminish downstream and would not be considered to be significant when considered at the wider catchment scale. Impacts may be minimised through suitable mitigation and best practice methods (see section 4 and 4.5).

3.4 Channel Diversion

3.4.1 Pitridh Aqueduct

The proposed aqueduct is 2,100m in length, and intercepts flows from the Pitridh and Chlachair Burns, together with several unnamed tributaries and unmapped overland flow routes, which can be seen on the UAV imagery and representative photos in Figure 3-2. The diverted sub-catchment drains an area of 7.06km^2, and flows of all frequencies would be diverted into the Earba reservoir.

Upstream of the proposed aqueduct, the channels have a transport dominated regime, i.e. steep, higher energy system with capacity to transport more sediment than the catchment supplies; and therefore any upstream impact would be highly localised in nature.

The key area of impact and sensitivity is identified as the reaches downstream of the Pitridh Aqueduct through the alluvial fan / plain, which are mostly classified as Type C. The total length of mainstem watercourses impacted by depletion of flows and sediment downstream of the aqueduct is estimated to be 2,836m. The footprint of the dam and inundation area would result in the loss of approximately 600m of channel length (mostly minor tributaries / ditches) at the downstream end of the system, on the approach to Loch Earba.

The diversion of upper catchment inflows away from the lower reaches would mean that unaffected minor tributaries, groundwater baseflows and rainwater would become the dominant sources of water. Throughflow would be significantly reduced, and for the most part the channels would contain sluggish flows or standing water; leading towards infilling by sediment deposition, vegetation growth and soil formation on channel margins, and a transition towards wetland over the long term. The main outlet from this area would be the buried aqueduct, and depending on the design of the hydraulic controls (particularly invert levels at its inlet) this would have the potential to affect water levels in the lower lying areas and in turn associated wetland dynamics and habitats. It is a project commitment that the structure will be designed to retain water at optimum levels for peatland in the area.

The Pitridh Aqueduct would also act as a barrier to sediment supply from upstream. The significant volume of sediments currently stored in the ‘sediment sink’ in this area would remain available, albeit they would be unlikely to be ‘re-worked’ in the absence of higher ‘channel forming’ flows (which drive morphological processes and dictate channel dimensions), meaning that this area would be relatively stable following development.

The sediments intercepted by the Pitridh Aqueduct would be subject to transport and storage through this new channel, and they would discharge into the loch at a more southerly position than they do currently. It is anticipated that sediment deposition would occur within the aqueduct, requiring consideration through design as well as active management.

In terms of the proposed aqueduct channel (Appendix C), the upper 1,100m would have a typical bed slope of 0.0079m/m, which under natural circumstances would typically align with a Type B (step-pool / plane bed) channel type, where boulder steps would naturally be expected. The steeper topography on the approach to Loch Earba is mitigated by meandering the channel across the slope in a switchback style (through the inundation extent area). This 1,006m ‘transition’ reach would have a typical slope of 0.025m/m and would align with a Type B or Type C (plane-riffle) typology. To prevent extreme flows entering this transition channel, which could destabilise morphology and habitats, a secondary high flow channel would be formed to divert excess flows. This channel would have a steeper slope (0.133m/m) aligning to a Type A (cascade) typology. The hydraulic controls at the inlet to the high flow channel would be designed to divert only excess flows, meaning that for the most part this channel would run dry.

An access road crossing is proposed just upstream of the flow split between the transition and high flow channels. This is sized with capacity to convey the 1 in 1,000 year flow including allowances for climate change and freeboard, and the structure would be built outwith the channel bed or banks. This bridge would not be anticipated to have a significant impact on morphological processes.

Figure 3-2: UAV imagery and representative photos of the area affected by the Pitridh Aqueduct

3.4.2 Moy Burn Realignment

A meandering realignment is proposed for the lower reaches of the Moy Burn, in order to provide alternative fish habitat outwith the proposed inundation extents of Loch Earba (Appendix D). A series of boulder steps and pools would enhance the diversity and stability of morphological and habitat features. No changes to the inflows of the burn are proposed, and so the main impacts will be the lengthening of the reach and the shallowing of the channel slope, which would reduce its stream power and sediment transport capacity, likely increasing rates of sediment deposition. Over time sediment size distribution would be anticipated to transition, with a higher proportion of smaller clasts being retained in the system.

The realigned reach will be 720m in length, replacing a current reach of 270m, resulting in a net gain of 450m in channel length. Associated with this will be a decrease in average channel slope from 0.079 to 0.038m/m (decrease of 47%). Both would align to Type B channels, albeit the proposed channel would be anticipated to have more shallow step pool / plane bed profile than the current channel, which transitions from steeper cascade through to step-pool.

To protect the proposed meandering channel and its habitats, the design proposes to utilise the current channel as a high flow channel, with excess flows being split off using a leaky weir arrangement. This channel will be activated only under high flow conditions, and therefore it will run dry for the majority of time, with flows being focussed down the new channel.

The energy losses associated with the leaky dam / splitting of flows, together with the bend in the channel and shallowing of slope, will likely lead to deposition of sediments at this location. It is anticipated that this effect would be relatively localised, but it will require mitigation in order to minimise potential for impacts such as flow bypassing or backing up of water affecting the proposed crossing a short distance upstream.

The proposed crossing is designed to accommodate a 1 in 1,000 year flow, including allowances for climate change and freeboard. The channel at the proposed bridge location is considered to be relatively stable, being fixed in position with bedrock / large boulder controls. The structure will be built outwith the channel bed / banks, and would not be anticipated to significantly impact upon hydromorphology.

3.4.3 Leamhain Catchwater Ditches

As shown in the designs in Appendix E, catchwater / cut-off ditches are proposed to the north and south of the reservoir to intercept natural catchment runoff from 50% of the Leamhain catchment, to isolate it from water circulating through the PSH system, mitigating against the transfer of INNS into the Allt Cam and River Pattack. The channels will be lined and designed to accommodate up to a 1 in 2 year flow, with any excess spilling into the Leamhain reservoir. In place of compensation flows from the dam outlet, natural flows directly from the cut-off ditches will form the dominant flows through the Leamhain Outfall.

High flows through the upper reaches of the Leamhain Outfall channel will be more or less limited to a 1 in 2 year flow, which is considered to be a channel forming flow. In effect these flows will bypass Loch Leamhain (which has a sediment sink effect) and may therefore introduce more bedload into the Leamhain Outfall channel, some of which may be sourced from scree slopes present on the valley sides. Particles would be of a size that may be mobilised by flows of up to 1 in 2 year event.

Within the Leamhain Outfall channel, the stream power of channel-forming flows will be capped and the maximum competent size of sediment particles that can be mobilised would be reduced. It is therefore anticipated that there will be an increased supply and retention of sediments through the Leamhain outfall, with a higher proportion of smaller sediment clasts than there are currently. This effect would diminish in the downstream direction as lateral inflows join the channel. With the moderation of extreme flows proposed, and the relatively resilient nature of the outfall channel (Type B to Type A), it is not anticipated that excess sediment deposition or destabilisation of the channel would be likely to occur, assuming best practice in construction and suitable monitoring and mitigation is in place.

Freshet releases will not be proposed as part of the management regime of the Leamhain Reservoir, given the INNS mitigation requirement. However, twin 1.2m diameter bottom outlet pipes have been included in the design, for emergency drawdown purposes only. A discharge weir would buffer outflows. If activated in an emergency, it is likely that significant mobilisation of sediment would occur through the Leamhain Outfall, potentially along with localised erosion of peaty banks. This impact would mimic a natural spate and as the channel is considered relatively resistant, with no sensitive receptors present in the immediate downstream reaches, it is anticipated that the significance of this impact would be low relative to natural background disturbance levels.

3.5 Associated Impacts

WFD waterbody classifications (see section 2.6) would be affected by the proposed scheme. While quantification of impact on status (e.g. Environmental Standards Test for morphology or Morphological Impact Assessment. System, MiMAS) is beyond the scope of the current appraisal, it is anticipated that the proposed Pitridh Aqueduct is the element likely to have the most significant impact in this respect. However, it is acknowledged as being an essential component of the scheme, in order to avoid flooding on the wrong side of the dam at the upstream end of Loch Earba (to be named 'Shuas Dam').

There will be a requirement to demonstrate that the proposed impacts on the classification of the Pitridh Burn, Allt Labrach and three Loch Earba Waterbodies are justifiable, in the context of national benefit of large scale renewables. This would be assessed across multiple quality factors (including hydromorphology, hydrology and ecology) and would be addressed through the derogation process outlined in *Regulatory Method (WAT-RM-34) Derogation Determination - Adverse Impacts on the Water Environment* (SEPA, 2017)[3].

Watercourse crossings to be modified or introduced by the proposed access routes through the development site would also have the potential to impact on morphology, at a localised level. These will be subject to careful design and construction to minimise scouring or impediment to sediment transport. Bridges will allow for climate change and blockage freeboard, and abutments will be clear of the channel. As such, the proposed bridges would be unlikely to impede sediment continuity. Crossing design will be assessed and mitigated separately through EIA and CAR licencing processes.

Flow diversion through the Allt Meall Ardruighe reservoir to the west via the buried aqueduct would represent an inter-subcatchment transfer of flows, although it is anticipated that the scale and nature of impact would be negligible in hydromorphological terms, particularly as the reservoir would attenuate the transmission of flows downstream.

The scheme during operation may have the potential to affect the Allt Cam, via modifications to the hydrological and sediment regime of the Leamhain Outfall; although the relative change is considered likely to be low or negligible when considered against the context of these high energy systems and the relatively larger size of the receiving waterbody (11.6km^2 upstream of the confluence).

[3] https://www.sepa.org.uk/media/149762/wat_rm_34.pdf

4 OUTLINE DESIGN MITIGATION AND RECOMMENDATIONS

4.1 Approach to Mitigation Design

Outline designs have been prepared with consultation input from SEPA and the project fish ecologist. Key recommendations to minimise / offset the impacts of the proposed PSH on hydromorphology have been incorporated into the design through an iterative process, and will be carried forward through the construction and operation of the scheme. Recommendations for specific waterbodies are provided in subsequent sections, and the following general recommendations are made to support future design phases:

1. Ongoing consultation with SEPA to agree any further requirements for waterbody status derogation and CAR Authorisation (Complex Licence).

2. Further hydromorphological assessments will likely be required in future phases to support sediment management / mitigation plans, which will be important particularly in the early stages of operation.

3. Channel design recommendations, which have been used as a basis for the design of the Pitridh Aqueduct and Moy Burn diversion, are summarised in Appendix G.

4. An outline structure for a site-specific sediment management plan is set out in Section 5. This will be developed further with SEPA prior to the project becoming operational.

4.2 Pitridh Aqueduct

The proposed design for the Pitridh Aqueduct is shown in Appendix C. Key design objectives, which have been incorporated in the outline design and recommendations of this report, are as follows:

- Upstream and downstream passage should be provided for salmonids and charr;
- Suitable water depths and velocities should be provided to allow fish passage;
- The channel should provide a suitably attractive flow to encourage migration;
- Spawning should not be encouraged within the inundation area;
- Natural shifting / evolution of channel features is undesirable;
- Measures should be resilient to accumulations of sediment and debris;
- Channel geometry should be capable of conveying a 1 in 1,000 year flow plus climate change;
- There should be a safe means to access the measures for inspection and maintenance.

SEPA have confirmed that the Pitridh Aqueduct would be classed as an engineered channel, and as such there would be no requirement to pass compensatory flows through to the lower reaches of the current watercourses.

Key mitigation measures that have been adopted in design, together with recommendations for future phases, are summarised as follows:

1. The Pitridh Aqueduct has been designed with consideration of local channel conditions within each tributary channel and minimises abrupt transitions in approach angles / curvature and bed slope which may induce instability. This principle should be taken forward through detailed design and construction.

2. With the Pitridh Aqueduct channel being designed to accommodate a 1 in 1,000 year + climate change design flood, a two-stage profile is proposed to safely distribute high energy flood flows whilst containing normal flows within a defined central channel with a dished base (reducing the risk of lower flows being overly shallow or 'lost' through coarse substrates). Inset channel sizings have been based on current climate conditions, to avoid over-sizing of the channel which may induce excess deposition. With natural bed and bank materials, it should be assumed that there will be a certain degree of self-adjustment of the channel to accommodate climate change over the long term.

3. Based on channel grade and energy regime, a step-pool channel design has been adopted, which is designed with fish passage as well as morphology in mind. Flows through the aqueduct will reflect natural flows that are sufficient to provide an attractive flow into Earba reservoir to stimulate migration, with steeper transition reaches further downstream designed to allow fish passage yet not encourage spawning within the inundation zone of Loch Earba.

4. The aqueduct has been considered an opportunity to create habitat to compensate for some of the habitat losses incurred elsewhere. To enable the channel to better mimic natural typology, the inset channel will be given a very slightly sinuous planform within the wider channel. Small pools (indicatively 1m depth) have been indicated on the inside of meander bends, for fish resting provision, which may naturally intercept sediment and so should be monitored and maintained as part of the sediment management plan.

5. To further mimic natural typology, the engineered channel bed has been designed to include a series of low-profile boulder steps which are considered to be at a height and frequency appropriate to the wider channel grade, and with a stable interlocking arrangement. Step pools will be sufficiently arranged so that energy is dissipated but the steps are low enough to still allow for passage of fish. Channel substrates would be formed using natural sediments local to the system, to provide a well-graded mix of sediment appropriate to the energy regime, arranged in a way that is appropriate for that setting.

6. The diverted channel would have a relatively shallow slope along most of its length, with increasing flows / stream power as the various tributaries join along its length. Design flow estimates and 1D hydraulic model outputs have been used to derive indicative morphological metrics to support the current design (including shear stress, stream power, bedload movement via Shields parameter and maximum competent particle size). The outcomes have been used to inform the sizing of the interlocking boulders that form the steps, for stability.

7. The bends in the transition channel will be formed with robust rock armour to avoid evolution of the channel. Furthermore, the proposed high flow channel will protect the stability of the transition channel and its habitats from extreme flows. The flow control structure is designed to allow flows up to Q1 to pass through the transition channel, and all excess flows will be diverted through the high flow cascade channel. Both channel designs are considered to be suitably resilient to these flow regimes.

8. The base of the aqueduct channel is designed to align with adjacent ground levels on the upslope side in such a way that groundwater baseflows can be intercepted. The downslope channel bank will be lined to prevent throughflow, which could otherwise lead to undermining over time.

9. Construction impacts, particularly the release of sediments into the system (anticipated to be relatively short-lived) will be mitigated through best-practice for in-channel engineering and surface water management (e.g. temporary erosion control, sediment traps, settlement lagoons, silt curtains). The bulk of the works will largely be done offline to limit impacts, with flows released

into the new channel following completion. The works will be supervised by an Environmental Clerk of Works.

10. As far as practicable and safe, the channel maintenance regime should encourage continued sediment transport processes and the formation of morphological features. The channel design includes sediment pools with suitable access provision and visibility, placed immediately downstream of tributary inflows, which would facilitate the removal of the bulk of any excess sediments deposited into the aqueduct. CCTV would facilitate regular monitoring of flow and sediment conditions.   Beyond this, any sediment management required should be strategically targeted to retain morphological diversity (e.g. berms, bars, step-pool features) and a degree of in-channel vegetation (so long as it does not compromise the functioning, stability or design capacity of the engineered channel).

11. The invert level of the entrance to the aqueduct is designed to avoid excessive backwater or drawdown effects from the Pitridh / Chlachair Burns and associated wetlands (i.e, it is placed close to existing ground level), in order to sustain hydrological integrity and peatland functioning on the valley floor.

12. The riparian planting proposed (Figure 4-1) would enhance hydromorphological and habitat diversity through the introduction of woody debris over the long-term.

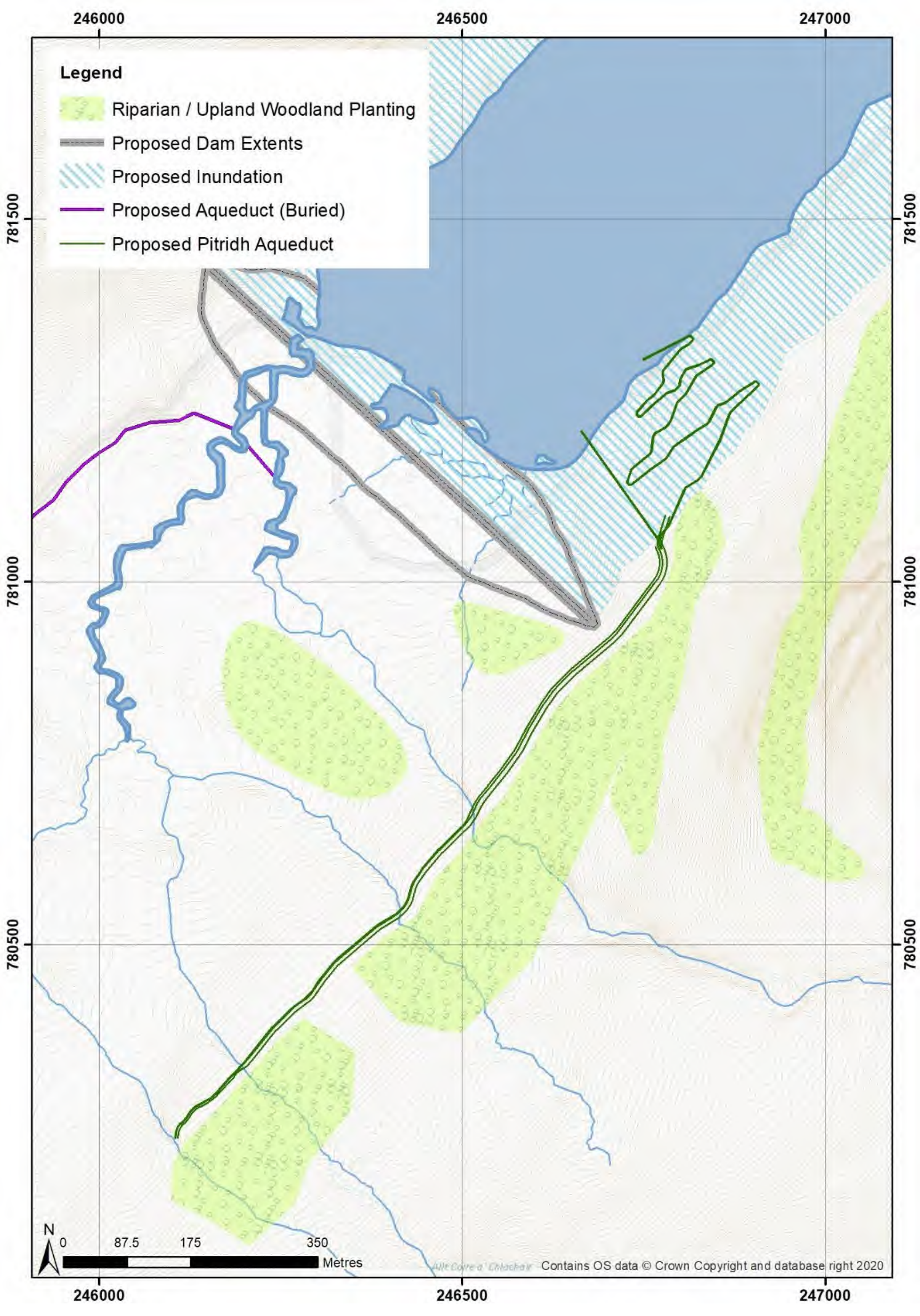


Figure 4-1: Proposed Pitridh Aqueduct and woodland planting

4.3 Moy Burn Fish Habitat Creation

Currently fish spawning and access from Loch Earba is limited to the lower reaches of the Moy Burn. Spawning would not be viable within the proposed inundation extents, and therefore it is proposed that fish spawning habitat is enhanced upstream to offset the impact, following SEPA feedback advice. The proposed modifications to the Moy Burn to enable fish habitat are indicated in Appendix D. Riparian tree planting is also proposed as part of the landscaping plans for the scheme.

The main channel of the Moy Burn between the apex of the alluvial fan and the valley floor is very steep and energetic, with large boulder substrates indicating high stream power. Channel conditions currently are very challenging for fish passage and suitable spawning habitat is negligible. The alluvial fan is naturally a dynamic and high energy environment where, in terms of hydromorphology alone, the optimal solution would be to remove the physical constraint of the embankment and leave natural river processes to continue with the expectation that the channel would migrate over the alluvial fan over the long term and possibly take on a multi-threaded form. However, where there is a drive to provide adequate compensatory fish spawning habitat, a degree of intervention would be required, with suitable buffering from the potentially damaging effect of spate flows.

Through consultation with the project fish specialist, it was recommended that spawning access for salmonids (and by proxy charr) would typically require up to a 3% slope, with slopes over 6% typically being considered impassable (depending on channel features present). To achieve this gradient within the steep valley setting, a sinuous route is required. Several potential routes were considered in an options appraisal process. The optimal route, in terms of engineering feasibility, morphological stability and fish passage, was determined to be a sinuous channel through the proposed promontory.

The lower reaches of the new channel are designed to be steeper so that spawning is discouraged within the inundation zone, and above this the slope of the new channel will slacken off to encourage spawning.

A constant flow would be required through the new channel to sustain fish, but to buffer it from the higher energy flows, the steeper main channel currently present would be maintained to convey spate flows. A leaky weir arrangement has been designed to control and split flows through the system, with flows up to 1m^3/s passing through the new channel, and all excess flows diverting through the current channel.

To generate suitable and varied flow conditions through the proposed channel, a sinuous route and step pool series will be formed, with fish resting pools inside bends. A wider / deeper pool will be formed at the western meander. Riparian trees would contribute woody debris and stabilise banks.

High channel-forming flows would continue to flow through the current channel and large boulders would be anticipated to dominate the substrate here over the long term. In the new meandering channel, smaller boulders, cobbles and gravels would be anticipated, which would be more conducive to spawning, with throughflow of water to keep any eggs in the gravel beds watered.

Ongoing sediment monitoring and targeted management will be required in this reach (particularly in the vicinity of the leaky barrier and transition into the new channel, where sediment deposition is likely to be focussed), to ensure continued function as designed. Timelapse or CCTV monitoring is recommended to support this.

4.4 Leamhain Outfall

During construction, drawdown of the existing loch will be required. Assuming a constant release equivalent to the catchment 1 in 2 year return period storm event, this is estimated to be required over 31 days. These flows would be considered morphologically effective, in terms of mobilising bed materials, a proportion of which may pass through the Allt Cam system. When considered against the background levels of disturbance and the resilience of the current channel network, this is not considered to be inappropriate. Ongoing monitoring of conditions throughout the drawdown period by an Environmental Clerk of Works is recommended.

During operation of the PSH, compensatory / freshet flows through the Leamhain dam are not recommended, on the basis that this would minimise the potential for INNS transfer. Rather, the catchwater ditches will provide compensatory flows on a natural flow regime up to the 1 in 2 year flow (approximately 1.5m^3/s). Sediment movements through the outfall watercourse should be monitored (and adaptively managed where necessary) as part of the sediment management plan (see section 5).

4.5 Allt Labrach

To mitigate the flow regime modification through the Allt Labrach, with input from SEPA, the provision of compensatory / freshet flows through the Shios dam has been incorporated in plans for the scheme (twin 1.2m diameter pipes with screened inlets). Environmental flows are not a requirement on the existing hydro scheme, and so the proposals have potential to provide a relative betterment to the current flow regime of the Allt Labrach, benefitting both hydromorphology and river habitats.

It is proposed that freshet flows of 5-7 m^3/s will be passed three times per year. Hydrological assessments available at the time of writing, including spill frequency data from the existing hydro scheme, indicate that this would align suitably with typical annual flood frequencies. The proposed freshet flows would be considered morphologically effective. The outlet arrangement is further designed with capacity to pass up to 20 m^3/s for emergency drawdown provision.

The Shios dam designs in Appendix F detail the scour protection provisions, including an outlet pond, which are designed to dissipate the energy of the water returning to the channel downstream, mitigating erosion in the vicinity of the discharge point into the receiving watercourse. These provisions will also fall under the design review by the panel Engineer as part of meeting the requirements of the Reservoirs (Scotland) Act, 2011.

Where excess sediments are removed from channels elsewhere in the scheme (e.g. in the sediment pools of the Pitridh Aqueduct), it is recommended that they are used to replenish sediments in the Allt Labrach. Any such sediment reintroductions should be strategically placed in a distributed manner and be timed with consideration of planned freshet releases. More detail on sediment management planning is given in section 5.

5 SEDIMENT MANAGEMENT RECOMMENDATIONS

Detailed sediment sampling / analysis or quantification of anticipated sediment supply rates is beyond the current scope of works, however, the existing hydropower scheme on Loch Earba, which has been in place for a number of decades, does provide a useful reference point for qualitative assessment. It is likely that the current physical sediment impedance by both hydro dams on Loch Earba would be relatively unchanged following the new scheme. However, by allowing for environmental flow releases and enhanced sediment monitoring and management, the proposed scheme has the potential to result in improvements to the downstream sediment supply and hydromorphological regime in the Allt Labrach, in particular.

Ardverikie Estates were consulted on previous sediment issues and management activities associated with the original hydropower scheme. They confirmed that they have never removed sediment from the existing hydro intake area or reservoir. A bund is visible within the loch (Figure 5-1) but it is understood that it is simply left over from the original construction of the intake and is a remnant of the coffer dam used by the original contractors. Sediment has never been removed from the upper channel or loch and low sediment volumes in the Allt Labrach indicate that through-flow of sediments are relatively low. It is therefore inferred that rates of long-shore drift are relatively low in Loch Earba (both under natural and existing impounded conditions).

Detailed bathymetry information is not available, but assuming that sediments arising from construction and operations are suitably managed and that no extreme sediment-generating flood events occur, it would be anticipated that it could take decades for any accumulations to arise that could substantially affect reservoir capacity to the point that intervention (e.g. dredging) would be required.

Figure 5-1: Sediment distribution upstream of the existing Loch Earba outlet

It is recommended that a sediment management plan is produced prior to the scheme becoming operational, following the indicative framework given in Figure 5-2, which starts with source control (reducing sediment production in the upper catchments with focus on any particular hotspot tributaries such as Moy Burn), minimising sediment deposition (bypass or pass-through features) and finally recovery and targeted reuse of sediments. Figure 5-3 indicates key focus areas for sediment management associated with the scheme.

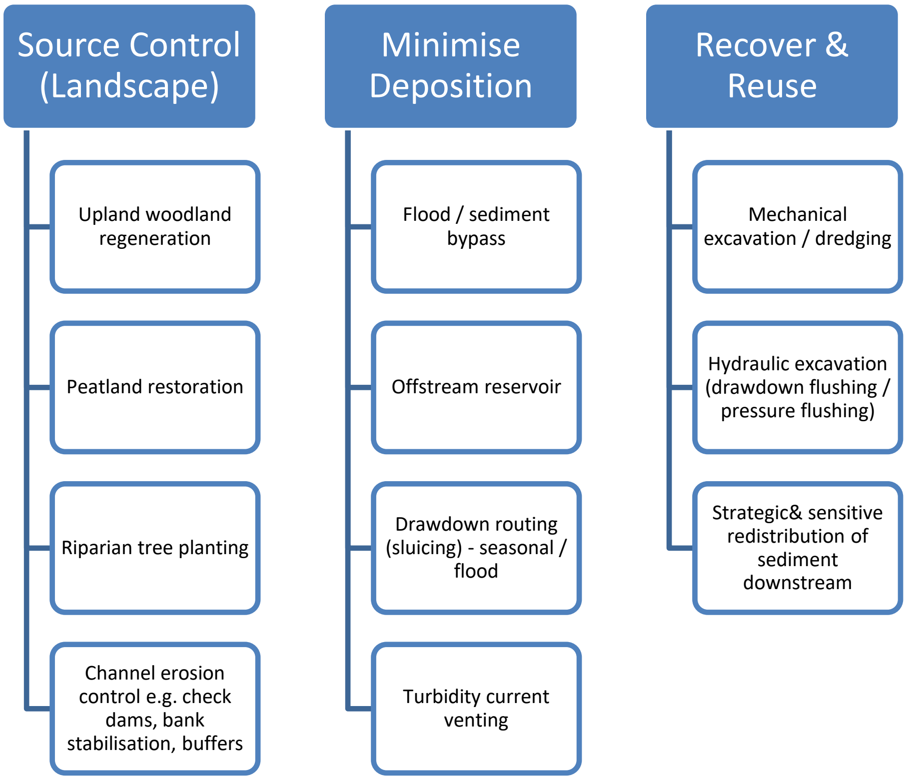


Figure 5-2: Indicative framework & example options for sediment management

Further recommendations for the sediment management plan are as follows:

1. The plan should follow best practice guidance set out in SEPA's Engineering in the water environment guidance series (WAT-SG-26) Good practice guide: Sediment management (SEPA, 2010)[4], which provides detailed guidance to support the appropriate locations, timing, volumes and frequency of sediment removal and re-introduction.

2. The plan should site-specific and be supported by monitoring; method statements; and toolbox talks for operators. It should include ongoing consultation with regulators and relevant stakeholders (e.g. downstream users, Lochaber District Salmon Fishery Board / Fisheries Trust) as necessary.

3. Measures should consider both short-term and long-term measures, as well as responsive measures for dealing with the aftereffects of significant unforeseen issues such as structure blockage, landslides or rare flood events. The plan should emphasize adaptive management informed by sediment monitoring, rather than a prescriptive, regular routine of management. Climate change effects should also be considered, with projections indicating that sediment transport volumes and competent sizes are expected to rise in line with flood peaks.

[4] https://www.sepa.org.uk/media/151049/wat-sg-26.pdf

4. Monitoring should involve a combination of measures including site observations; regular inspection of access road crossings, diversion channel and flow control structures; and depth soundings / bathymetric survey / satellite imagery of the loch. Timelapse camera or CCTV technology with telemetry may be utilised to proactively manage sediment management at key locations.

5. Any in-channel works should avoid spawning periods (indicatively October-May, to be confirmed by fish specialist).

6. Excess sediments should be selectively removed from the diversion channels (to maintain design capacity and function while maintaining step-pool / habitat features) and replaced downstream in a natural channel which has been identified as being suitable for sediment reintroduction (considering factors such as spawning potential, sediment load, stream power and the capacity of the river to re-work sediments). The Allt Labrach has been identified as a key location for sediment reintroduction.

7. Strategic redistribution of sediments should focus on restoring sediment continuity and habitat diversity downstream. Care should be taken to sensitively place sediments along the channel margins in such a way as to prompt the river to re-work them during spate or freshet events, encouraging redistribution along the length of the channels in the form of natural deposition features (e.g. variety of bars, floodplain deposits). Placement should be strategically planned, for instance to avoid spawning periods, smothering of habitats or the formation of large unnatural deposits that would not readily be re-worked by the river or instigate flooding / lateral erosion / structure blockage issues.

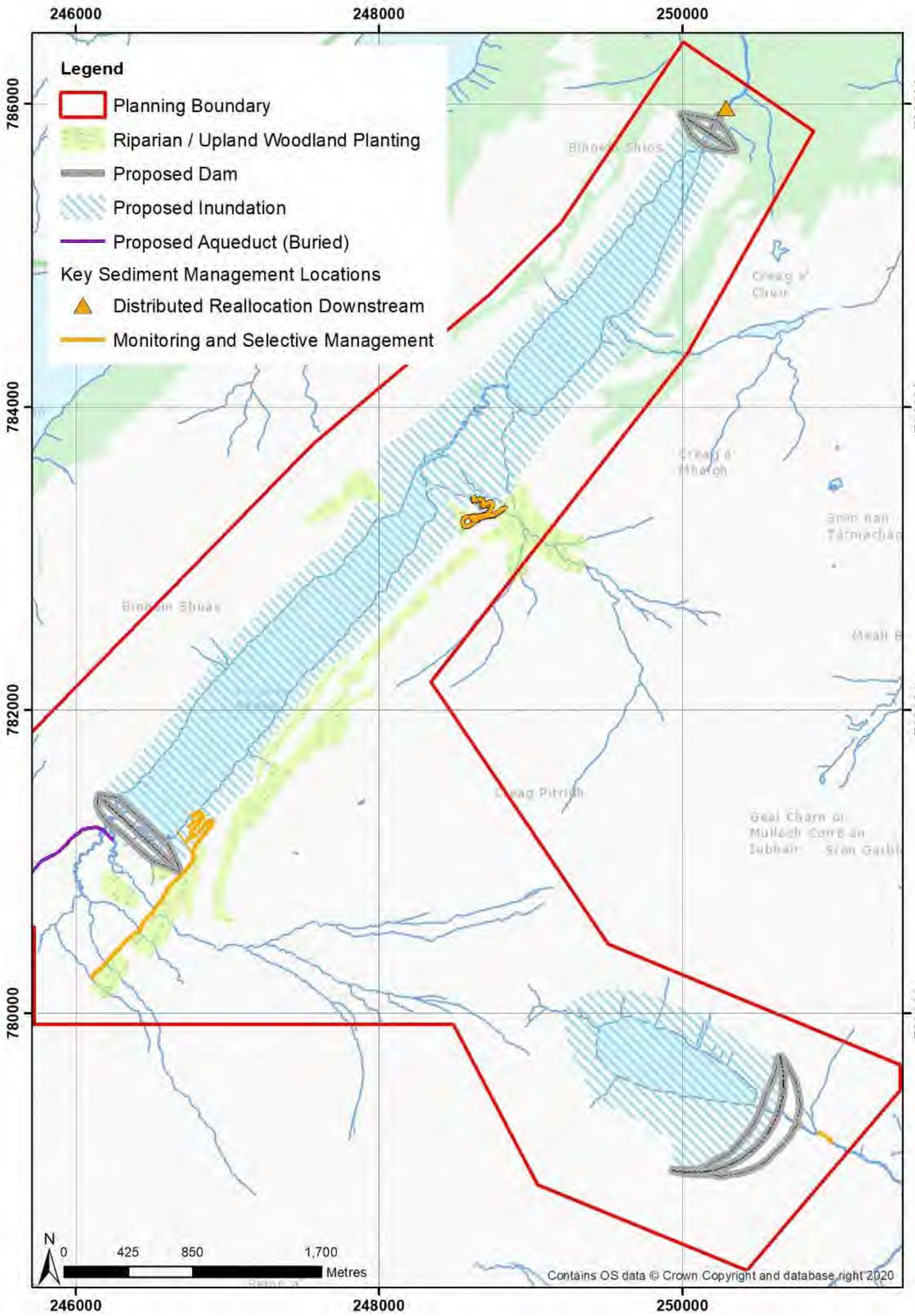


Figure 5-3: Indicative key locations for sediment management

6 CONCLUSIONS

A hydromorphological assessment has been undertaken to inform the design of the proposed Earba Pumped Hydro Scheme, as well as planning and CAR applications. The hydromorphological character of key waterbodies has been assessed through a combination of spatial data analysis and site walkover survey, with a focus on channel forming processes. The potential impacts of the proposed Pitridh Aqueduct, and of the proposed impoundments on the Allt Labrach and Leamhain Outfall, have been appraised.

The upper and lower parts of Loch Earba and its connecting channel would fundamentally be combined as part of the scheme. It is considered that the relative impact of the dam construction on the downstream Allt Labrach would be low in the context that it is already artificially impounded for hydropower purposes. Proposed environmental flow releases and sediment reintroduction measures would be likely to improve the morphological processes and conditions in the Allt Labrach, relative to its current baseline. The proposed dam on the Leamhain would enhance the existing natural impoundment, although the proposed catchwater ditches would sustain a natural flow regime through the outflow channel from approximately half of the catchment area. Both watercourses are high energy systems which are relatively resistant to physical change, in hydromorphological terms. The effects would diminish in the downstream direction, and the lengths of the affected reach are also physically limited by the presence of lochs / reservoirs downstream.

The steep upper reaches of the tributaries proposed for diversion would be unaffected by the scheme, with the most significant impacts being in the immediate vicinity and downstream of the aqueduct. Here, ‘Type C’ river typologies would be impacted by reduced sediment supply as well as flows. Over time, it is anticipated that the affected reaches would adjust and transition towards a network of smaller channels flowing through wetland.

Channel diversions in the Pitridh and Moy Burn systems have been designed in collaboration with fish specialists and engineers, and in consultation with SEPA, to optimise these channels in terms of hydromorphological processes, stability and fish habitat. Ongoing monitoring and sediment management will optimise the sustained functioning of these channels.

The level of design and hydromorphological assessment undertaken to date is considered appropriate for the stage of the planning process. It is understood that consultation with SEPA on the derogation and CAR licencing process is ongoing, and further hydromorphological assessments will be undertaken as part of the future detailed design of the scheme. The sediment management plan for the scheme will develop alongside the detailed design process and will be refined through the construction and operational phases taking an adaptive approach.

APPENDICES

A REPRESENTATIVE PHOTOGRAPHS

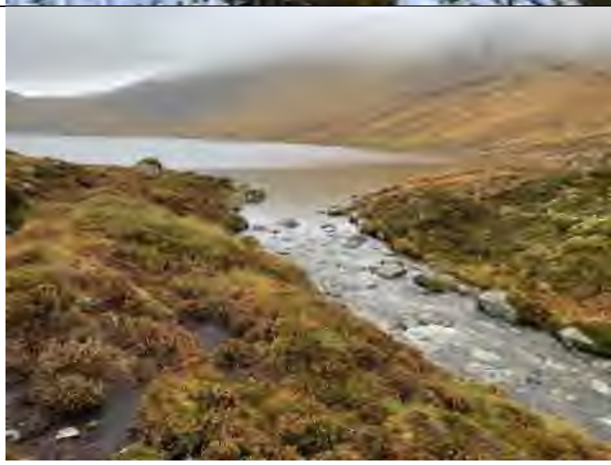
1. Pitridh Burn Upper Reaches	
2. Pitridh Burn Middle Reaches	
3. Pitridh Burn Lower reaches	

4. Chlachair Burn Middle Reaches	
5. Chlachair Minor Tributary	
6. Chlachair Burn Lower Reaches	

7. Existing dam at outlet of the upper (western) Loch Earba (noting temporary piped solution due to sluice maintenance issue)	
8. Mid Lochan na h-Earba: Upper Reaches (downstream of existing hydro dam)	
9. Mid Lochan na h-Earba: Lower Reaches	
10. Typical sediments associated with longshore drift on southern bank of Lower Loch Earba	

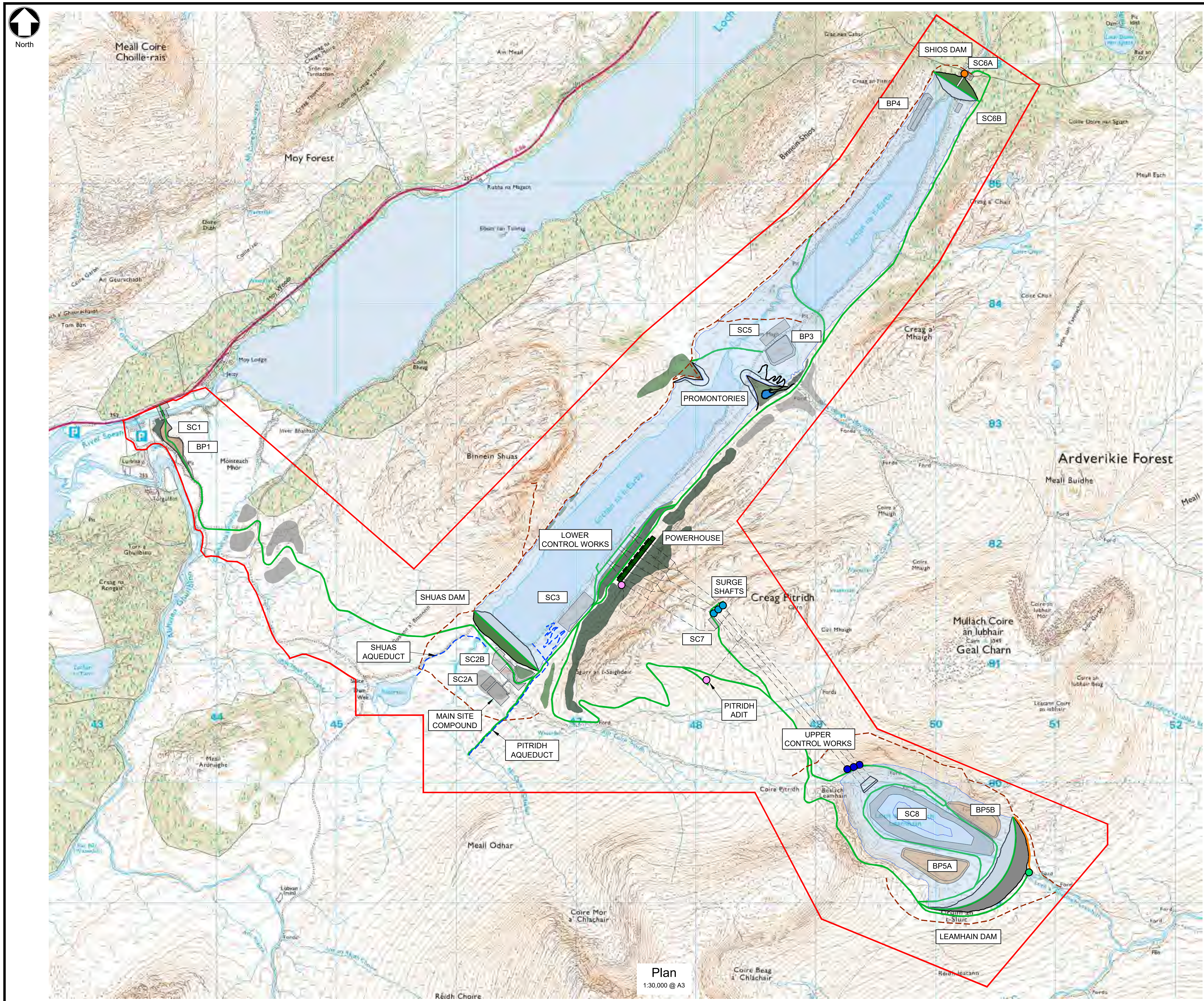
11. Existing Dam at Loch Earba Outflow to Allt Labrach	
12. Allt Labrach Upper Reaches	
13. Allt Labrach Lower Reaches	

14. Moy Burn Upper Reaches	
15. Moy Burn Upper Reaches: Southern (Active) Branch with embankment to right of image	
16. Moy Burn Lower Reaches: Southern Branch	

17. Moy Burn: Northern Branch	
18. Moy Burn: Central Branch	
19. Leamhain Outfall (Natural Control)	

20. Leamhain Outfall Upper Reaches	
21. Leamhain Outfall Middle Reaches	
22. Leamhain Outfall Lower Reaches (fore) and confluence with Allt Cam (rear)	

B PROPOSED SCHEME ARRANGEMENT



IF IN DOUBT - ASK

LEGEND

- Planning Boundary
- Inundation
- Dam
- Intake
- Surge Shaft
- Adit
- Shios Valve House and Fish Pool
- Leamhain Upper Gate House
- Leamhain Lower Valve House
- Tunnel
- Powerhouse
- Borrow Pit
- Compound
- Promontories
- Aqueduct / Diversion Channel
- Access Bridge
- PSH Track
- Estate Track / Footpath
- Leamhain Dam Spillway
- Loch a' Bhealaich Leamhain Proposed to be Drawn Down to +612m During Construction
- New Tree Planting - Riparian Mix
- New Tree Planting - Upland Mix
- Moy Burn Habitat

0 500m 1000m

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P1	26.01.23	MH	FOR PLANNING	DT	GMcG

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TITLE
SCHEME ARRANGEMENT FIGURE 2.2

SIZE	SCALE AT A3	STATUS
A3	1:30,000	PLANNING

DRAWING NUMBER	REVISION
EAR/GEL/002	P2

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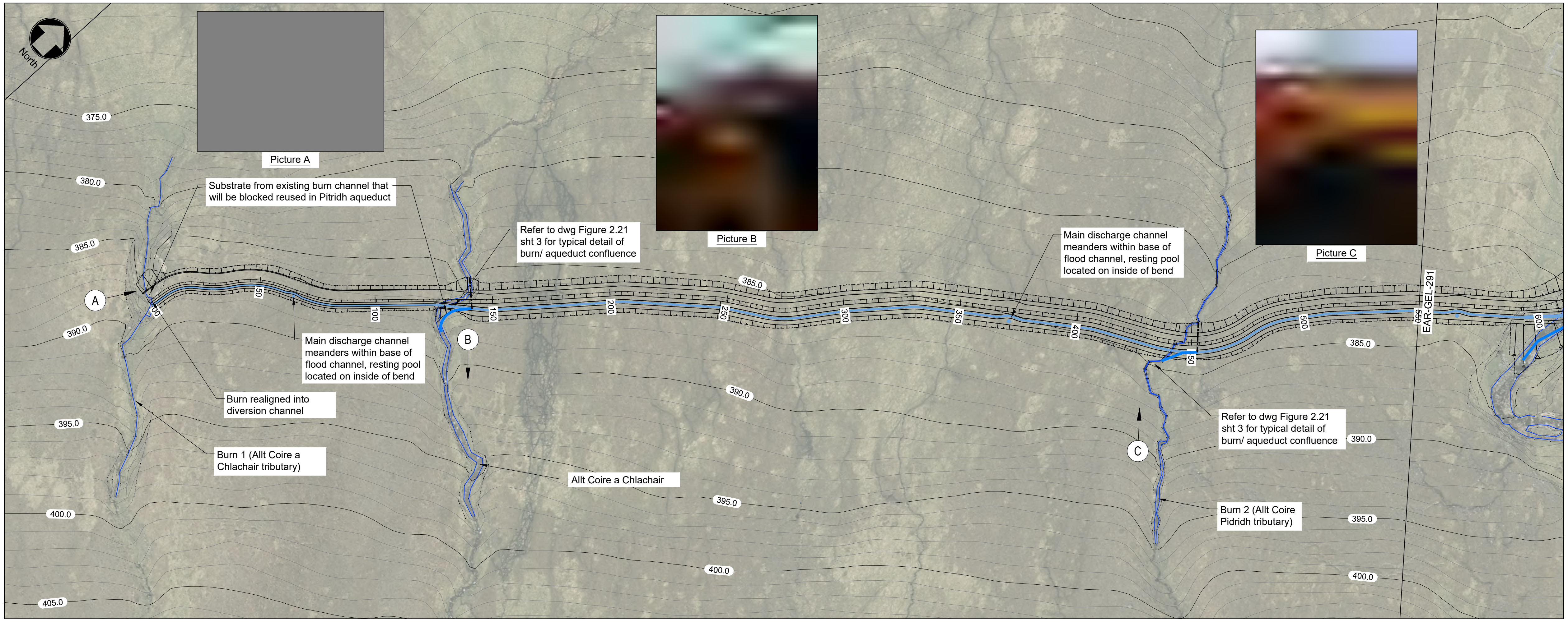
C PROPOSED PITRIDH AQUEDUCT DESIGN



Plan

1:2000 @ A3

0 50m 100m

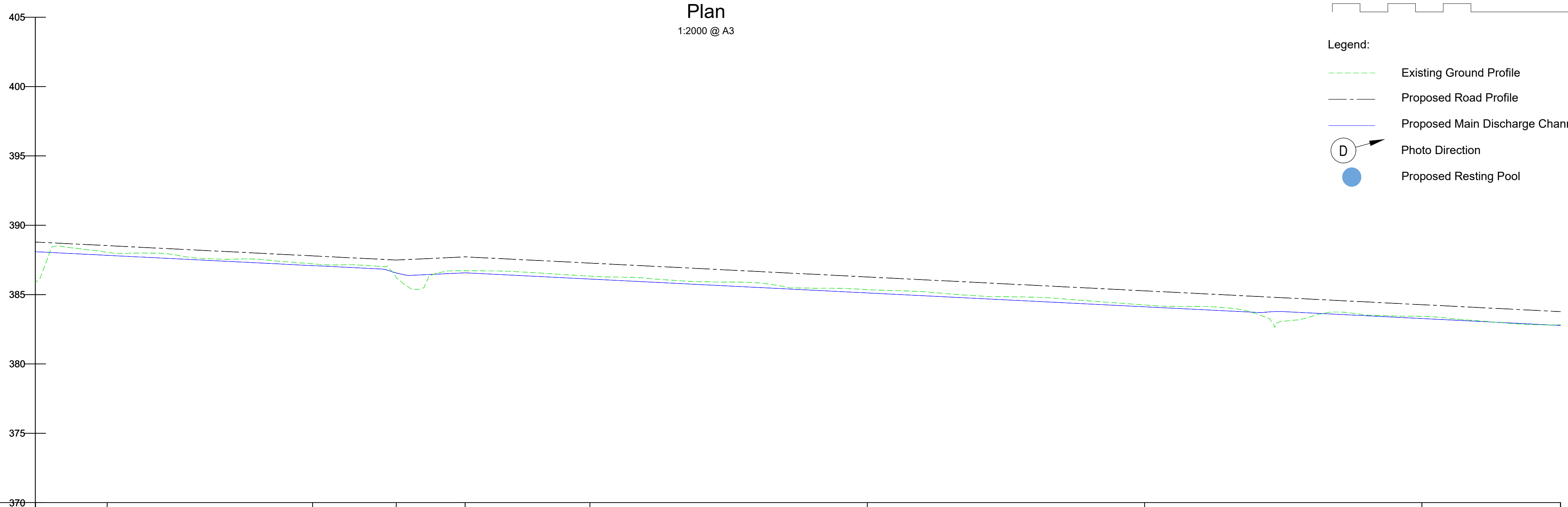
Legend:

- Existing Ground Profile
- Proposed Road Profile
- Proposed Main Discharge Channel Profile
- (D) Photo Direction
- Proposed Resting Pool

LONGITUDINAL SECTION

(A-DIVERSION CHANNEL)

CHAINAGE: 0 TO 550
SCALE: H 1:1000, V 1:200



Chainage	0.000	25.899	100.000	130.136	154.987	200.000	300.000	400.000	500.000	550.000
Existing Levels	385.885	388.050	387.214	386.255	386.721	386.336	385.354	384.255	383.432	382.818
Proposed Levels	388.791	388.532	387.791	387.490	387.722	387.271	386.271	385.271	384.271	383.771

Aqueduct Section Refer to Figure 2.21 Sheet 1	Section 1 1:100	Section 2 1:100	Section 3 1:100

0 50m 100m

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NOTES

Aqueduct Notes

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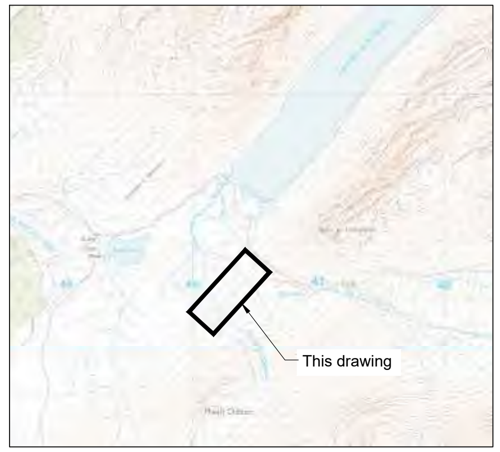
8. CCTV coverage at the confluence of existing burn and channel would will provide real time monitoring of flow and sediment conditions.



Location Plan

1:30,000 @ A1

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P2	06.12.24	MW	CAR LICENCE SUBMISSION	DT	GRM
P1	02.02.24	MW	FOR PLANNING	DT	GRM

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TITLE

PITRIDH CHANNEL DIVERSION PLAN AND LONG SECTION FIGURE 2.20 - SHEET 1

SIZE	SCALE AT A3	STATUS
A3	1:2000 @ A3	PLANNING

DRAWING NUMBER	REVISION
EAR/GEL/290	P2

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NOTES

Aqueduct Notes

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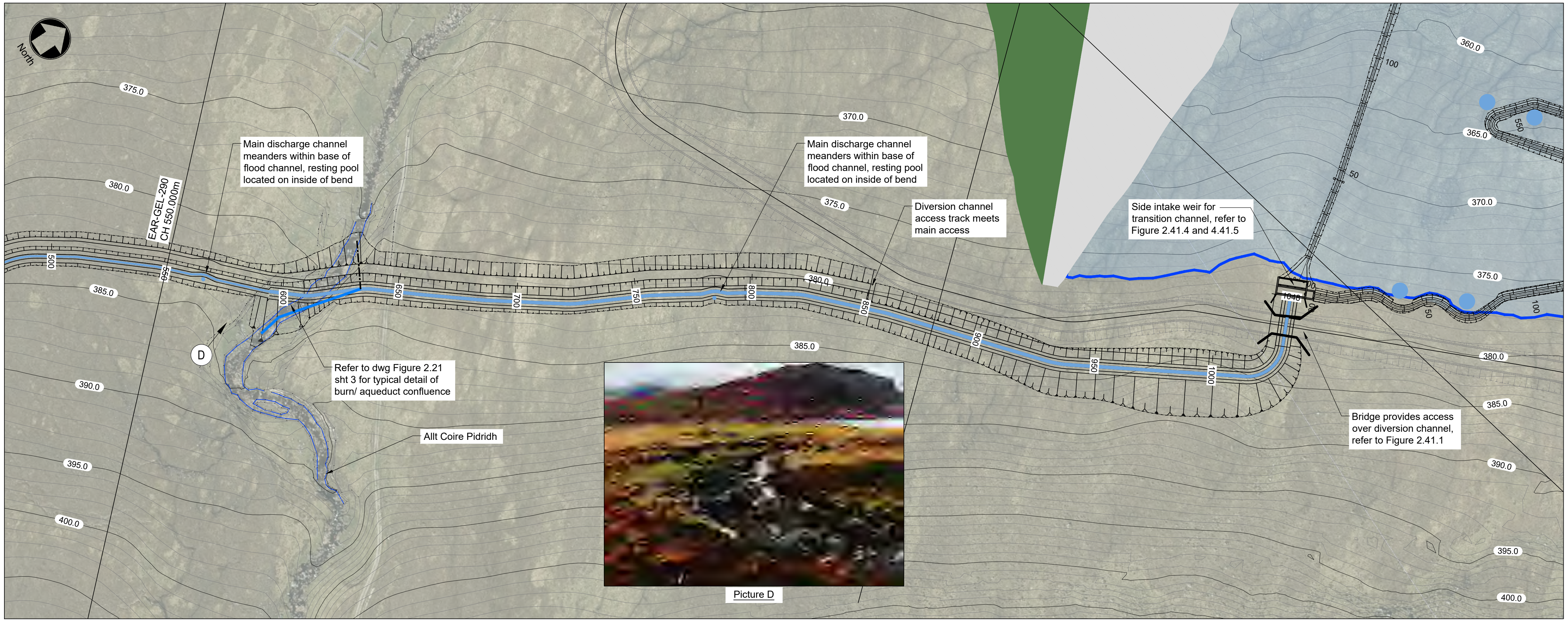
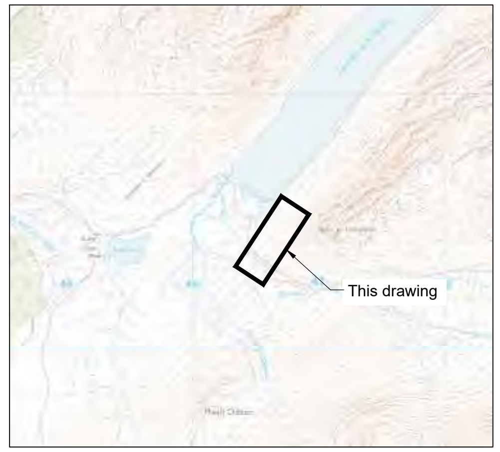


Plan

1:2000 @ A3

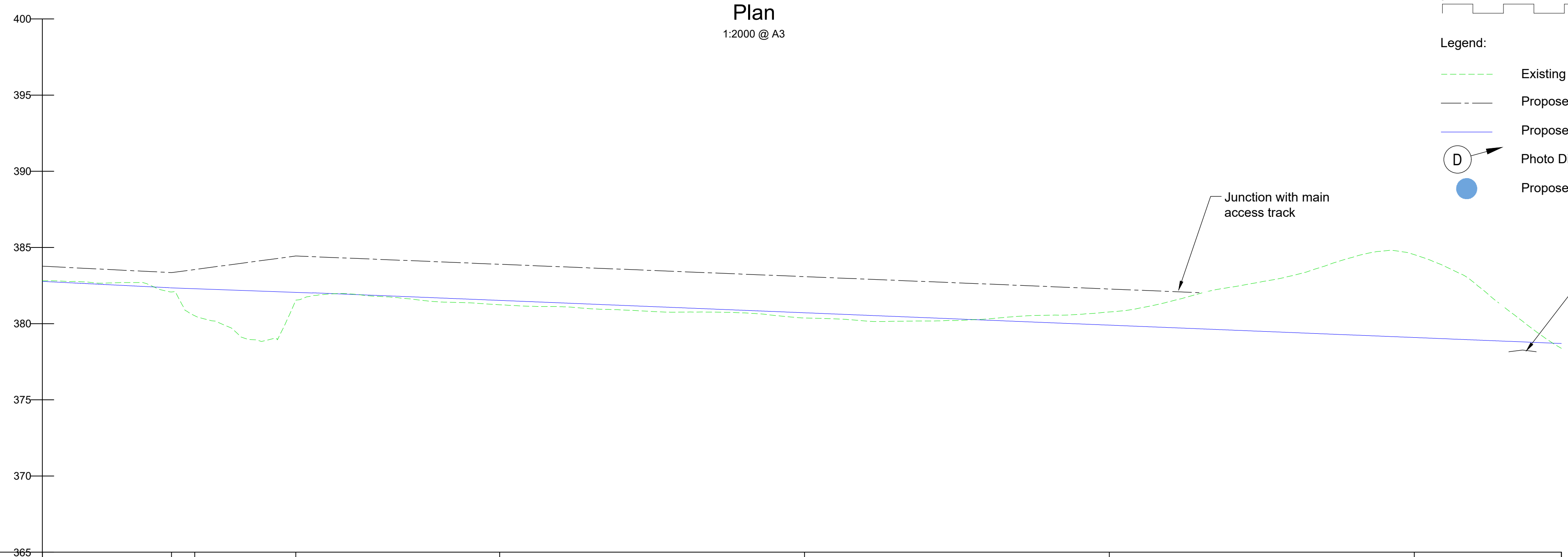
Legend:

- Existing Ground Profile
- Proposed Road Profile
- Proposed Main Discharge Channel Profile
- Photo Direction
- Proposed Resting Pool



Location Plan

1:30,000 @ A1



LONGITUDINAL SECTION

(A-DIVERSION CHANNEL)

CHAINAGE: 550 TO 1048
SCALE: H 1:1000, V 1:200

Chainage	550.000	592.375	600.000	633.107	700.000	800.000	900.000	1000.000	1048.262
Existing Levels	382.818	382.081	380.517	381.527	381.240	380.375	380.768	384.531	378.379
Proposed Levels	383.771	383.348	383.552	384.440	383.897	383.085	382.273	381.462	381.070
Aqueduct Section Refer to Figure 2.21 Sheet 1	Section 3 1:100			Section 4 1:100					

0 50m 100m

REV	DATE	DRAWN	NOTES	CHK'D	APP'D
P2	06.12.24	MW	CAR LICENCE SUBMISSION	DT	GRM
P1	02.02.24	MW	FOR PLANNING	DT	GRM

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TITLE
PITRIDH CHANNEL DIVERSION PLAN AND LONG SECTION FIGURE 2.20 - SHEET 2

SIZE	SCALE AT A3	STATUS
A3	1:2000 @ A3	PLANNING

DRAWING NUMBER	REVISION
EAR/GEL/291	P2

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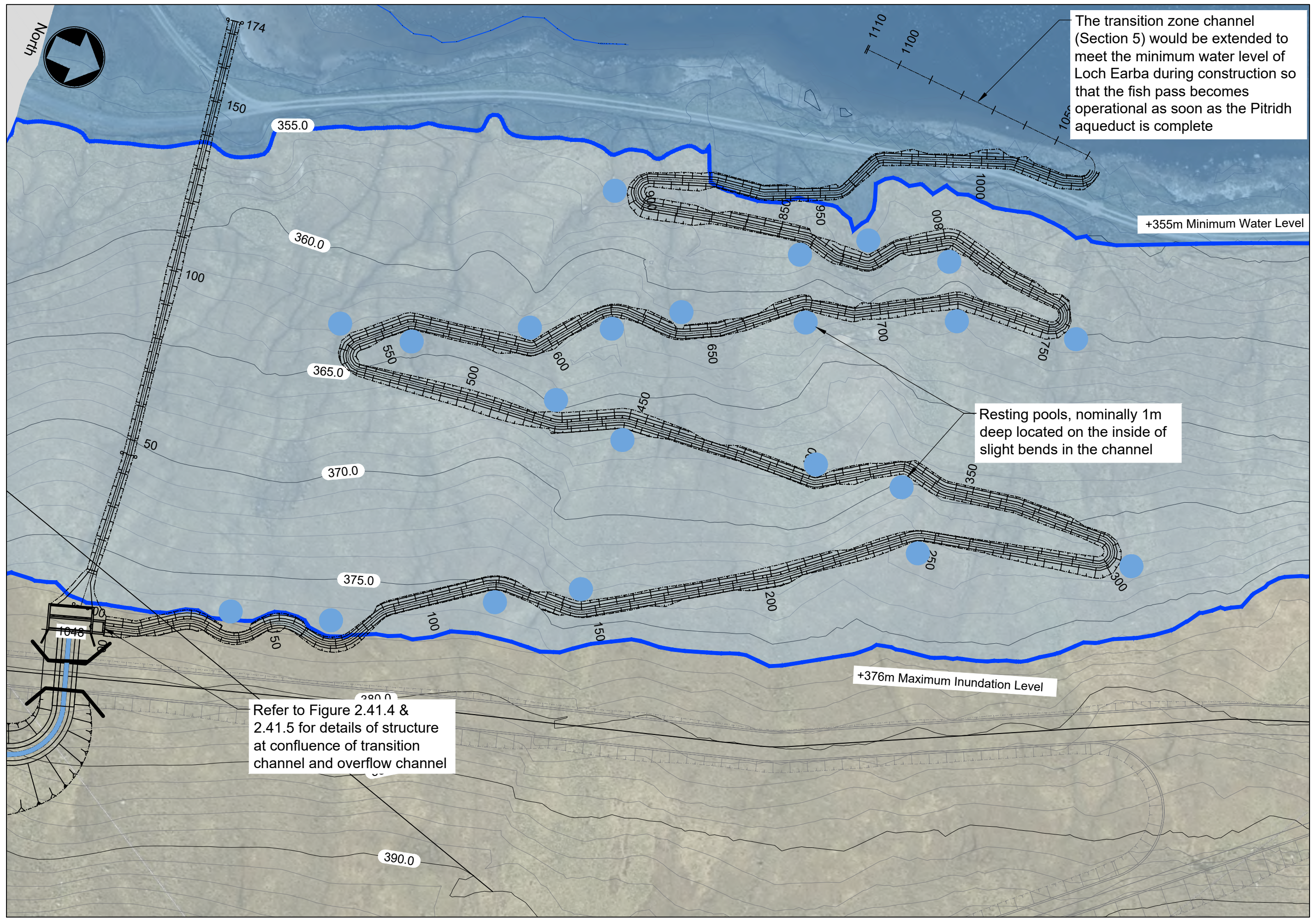


Plan
1:2000 @ A3

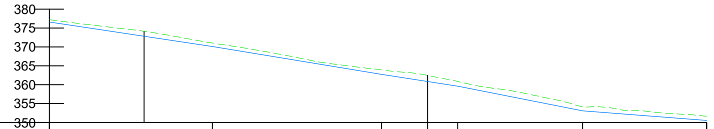
Legend:

- Existing Ground Profile
- Proposed Road Profile
- Proposed Main Discharge Channel Profile
- Photo Direction
- Proposed Resting Pool

LONGITUDINAL SECTION

(A-SECTION 6)

CHAINAGE: 0 TO 174
SCALE: H 1:250, V 1:250



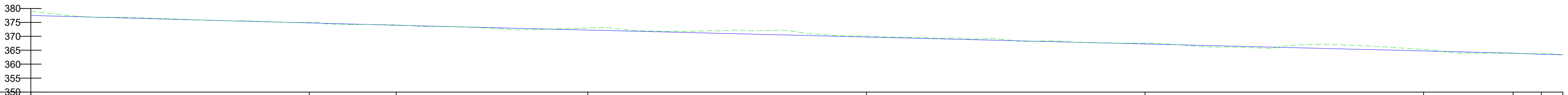
Chainage	0.000	43.063	87.781	100.000	107.989	140.943	173.759
Existing Levels	377.196	371.038	363.933	362.469	360.864	354.153	351.662
Proposed Levels	376.601	370.130	362.781	360.881	359.638	353.131	350.576
Aqueduct Section Refer to Figure 2.21 Sheet 1	Section 6 Gradient Varies, typically 10% - 14%						

0 50m 100m

LONGITUDINAL SECTION

(SC3 CHANNEL)

CHAINAGE: 0 TO 550
SCALE: H 1:1000, V 1:1000



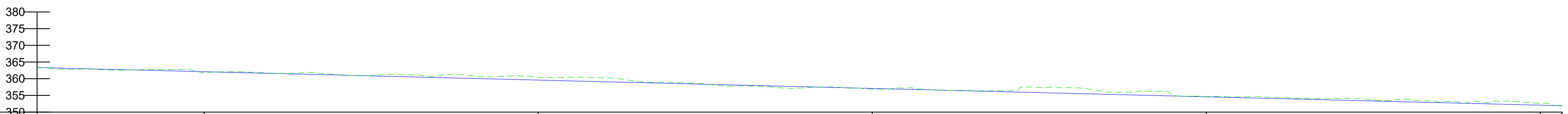
Chainage	0.000	100.000	131.168	200.000	300.000	400.000	500.000	532.130	542.291	550.000
Existing Levels	379.116	375.019	374.142	373.058	370.089	367.531	365.295	363.864	363.759	363.435
Proposed Levels	377.500	374.814	373.977	372.256	369.756	367.256	364.756	363.953	363.546	363.353
Aqueduct Section Refer to Figure 2.21 Sheet 1	Section 5 1:40									

0 50m 100m

LONGITUDINAL SECTION

(SC3 CHANNEL)

CHAINAGE: 550 TO 1006
SCALE: H 1:1000, V 1:1000



Chainage	550.000	600.000	700.000	800.000	900.000	1000.000	1006.452
Existing Levels	363.435	361.867	360.429	356.854	354.634	352.684	352.037
Proposed Levels	363.353	362.103	359.603	357.103	354.603	352.103	351.942
Aqueduct Section Refer to Figure 2.21 Sheet 1	Section 5 1:40						

0 50m 100m

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NOTES

Aqueduct Notes

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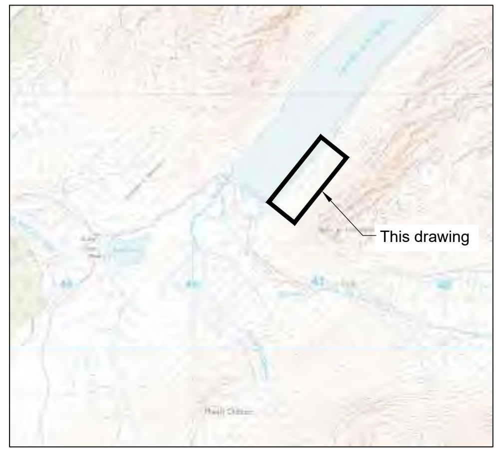

Location Plan
1:30,000 @ A1

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P2	06.12.24	MW	CAR LICENCE SUBMISSION	DT	GRM
P1	02.02.24	MW	FOR PLANNING	DT	GRM

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TITLE
PITRIDH CHANNEL DIVERSION PLAN AND LONG SECTION FIGURE 2.20 - SHEET 3

SIZE	SCALE AT A3	STATUS
A3	1:2000 @ A3	PLANNING

DRAWING NUMBER	REVISION
EAR/GEL/292	P2

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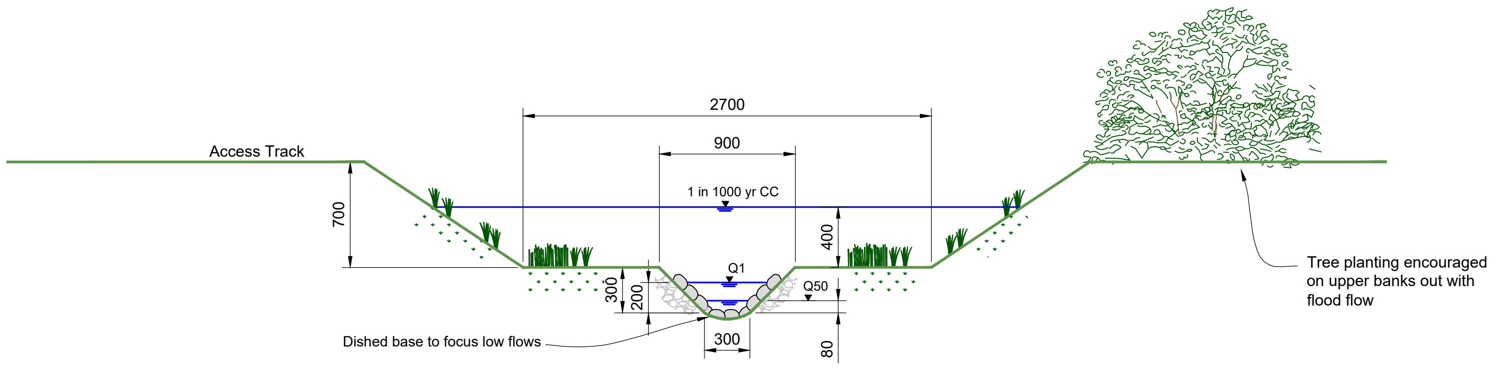
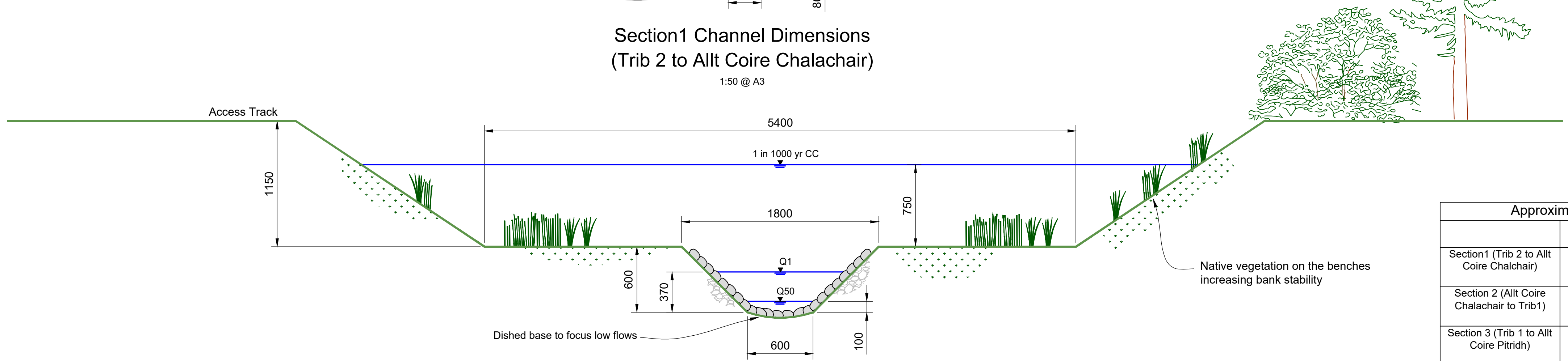
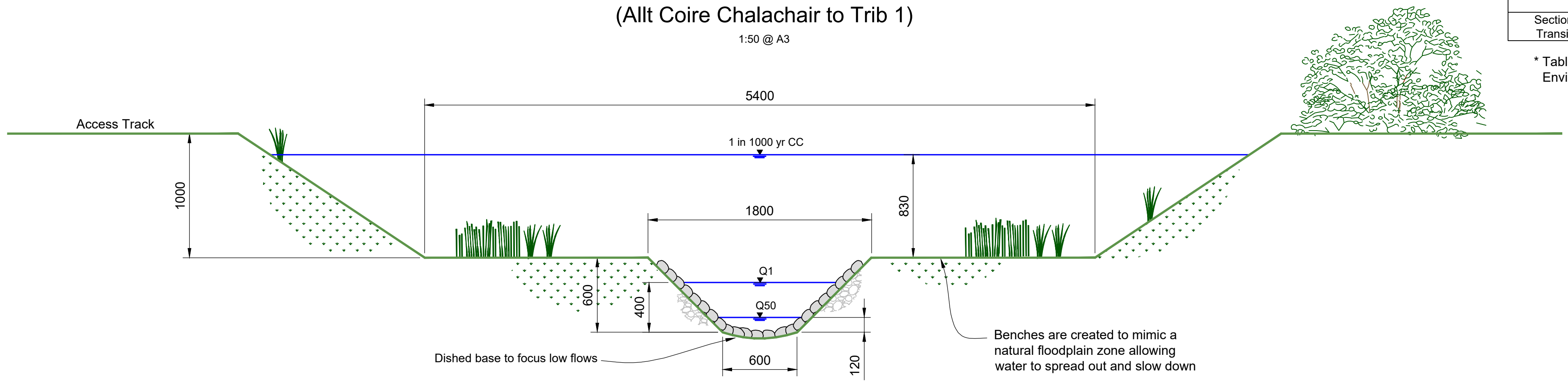


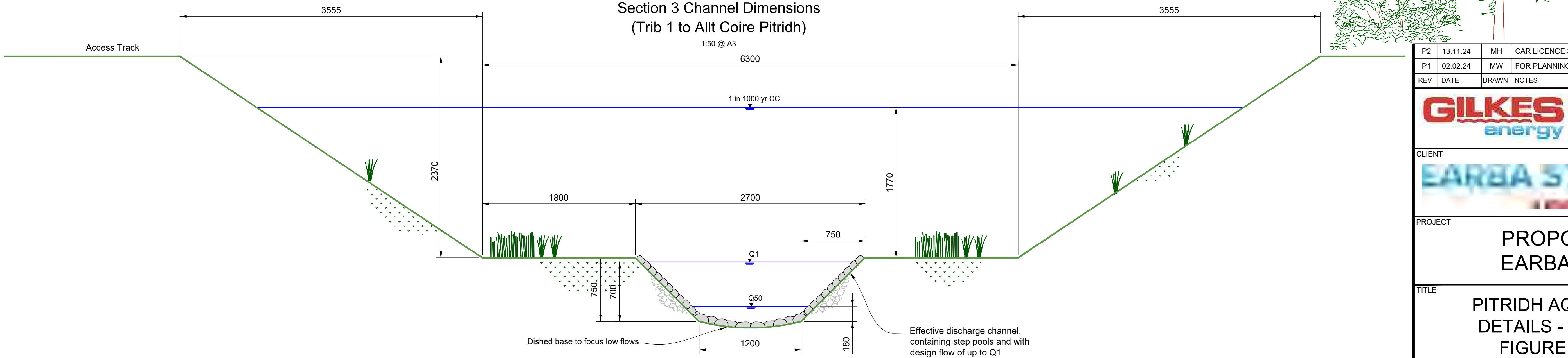
Section1 Channel Dimensions
(Trib 2 to Allt Coire Chalachair)
1:50 @ A3



Section 2 Channel Dimensions
(Allt Coire Chalachair to Trib 1)
1:50 @ A3



Section 3 Channel Dimensions
(Trib 1 to Allt Coire Pitridh)
1:50 @ A3



Section 4 Channel Dimensions
(Allt Coire Pitridh to Loch Earba transition zone)
1:50 @ A3

0 1.25m 2.5m

IF IN DOUBT - ASK

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Approximate velocities for Pitridh Aqueduct (m/s)

	Q90	Q50	Q1	1 in 10
Section1 (Trib 2 to Allt Coire Chalchair)	0.2200	0.3200	0.5900	0.9700
Section 2 (Allt Coire Chalachair to Trib1)	0.3500	0.4200	0.9100	1.5700
Section 3 (Trib 1 to Allt Coire Pitridh)	0.3800	0.4900	0.9400	1.7200
Section 4 (Allt Coire Pitridh to Loch Earba)	0.4900	0.6900	1.3500	1.9500
Section 5 Earba Transition zone	0.7300	0.9100	2.1600	N/A

* Table above meets the requirements of Table 5 in the Environmental Agency Fish Pass Manual

REV	DATE	DRAWN	NOTES	CHK'D	APP'D
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P1	02.02.24	MW	FOR PLANNING	DT	GMcG

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TITLE
PITRIDH AQUEDUCT DETAILS - SHEET 1
FIGURE 2.21.1

SIZE A3 | SCALE AT A3 1:50 | STATUS PLANNING

DRAWING NUMBER EAR/GEL/295 | REVISION P2

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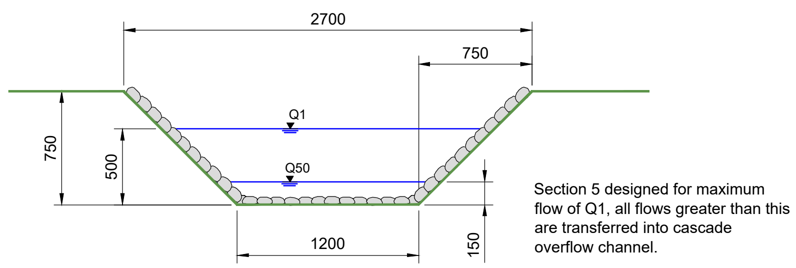
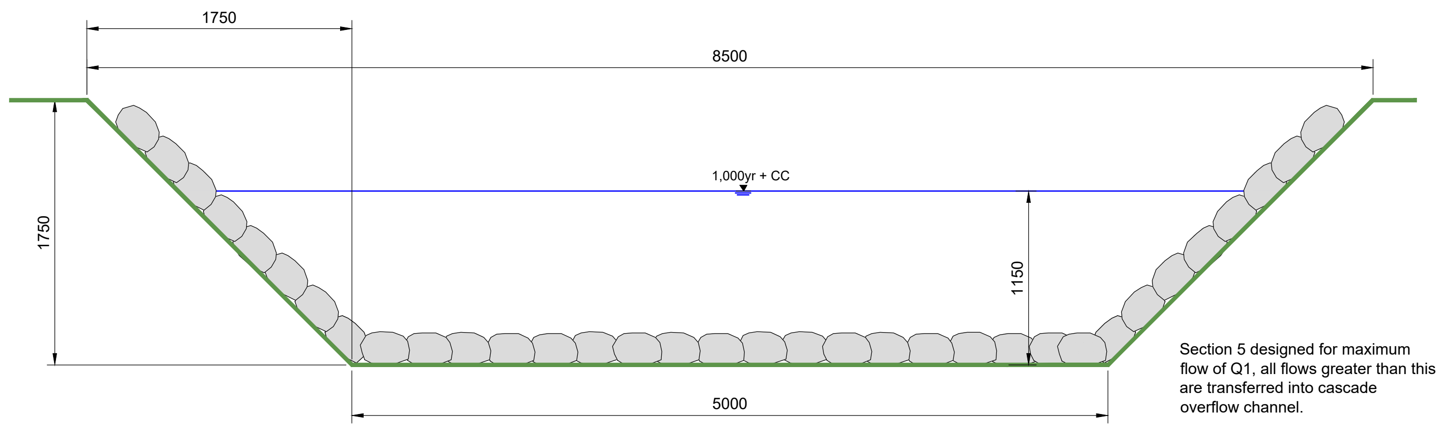
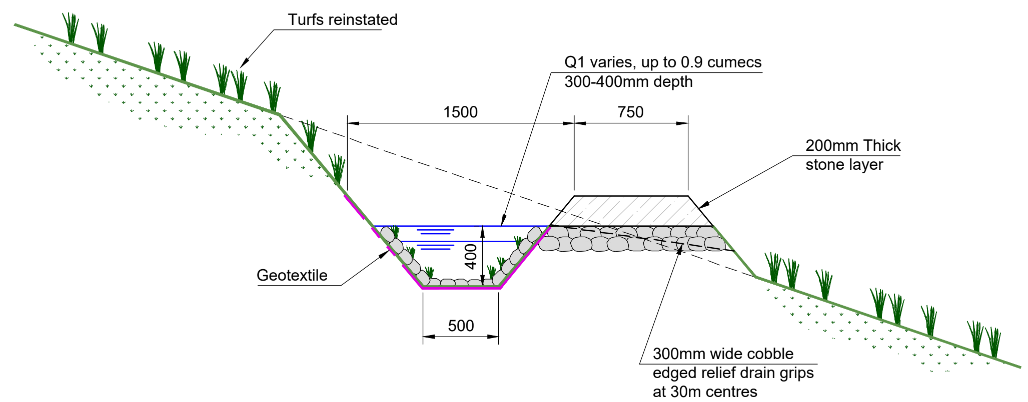


Section 5 Channel Dimensions
(Loch Earba transition zone and Moy Habitat Channel)
1:50 @ A3

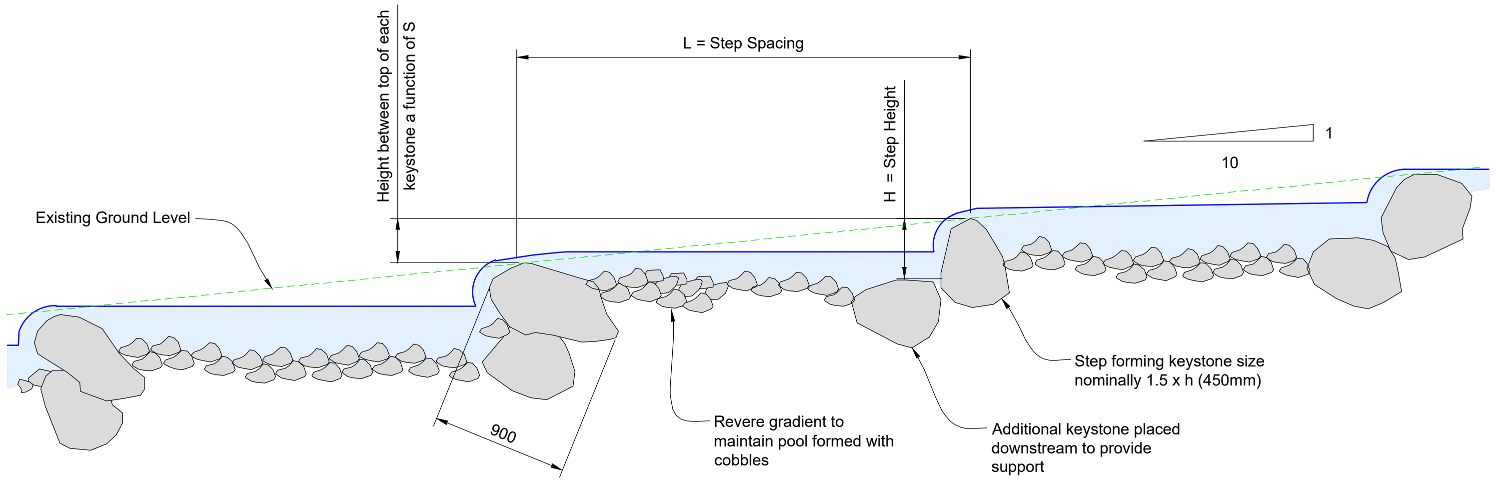


Section 6 Channel Dimensions
(Loch Earba transition zone overflow channel)
1:50 @ A3

Cascade Parameters for Pitridh Aqueduct overflow and Leamhain catchwater					
	S = Slope	H= Step height (m)	L = Length between steps (m)	Drop between pools (m)	Typical Keystone Size (mm)
Section6 (Pitridh Overflow)	10%	0.400	3	0.3	600
Leamhain catchment transfer ditch	10%	0.2500	2.5	0.250	400.000
Moy Spillway	10%	0.400	3	0.3	600



Typical 0.75m Wide Footpath & Catchwater
Cut-off Ditch at Leamhain
1:50 @ A3



Typical Cascade Detail
Pitridh Aqueduct Overflow and Leamhain
Catchwater Ditch and Moy Spillway Channel
1:50 @ A3

0 1.25m 2.5m

P1	13.11.24	MH	CAR LICENCE SUBMISSION	DT	GMcG
REV	DATE	DRAWN	NOTES	CHK'D	APP'D

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PROJECT
PROPOSED
EARBA PSH

TITLE
PITRIDH AQUEDUCT
DETAILS - SHEET 2
FIGURE 2.21.2

SIZE A3 | SCALE AT A3 1:50 | STATUS PLANNING

DRAWING NUMBER EAR/GEL/296 | REVISION P1

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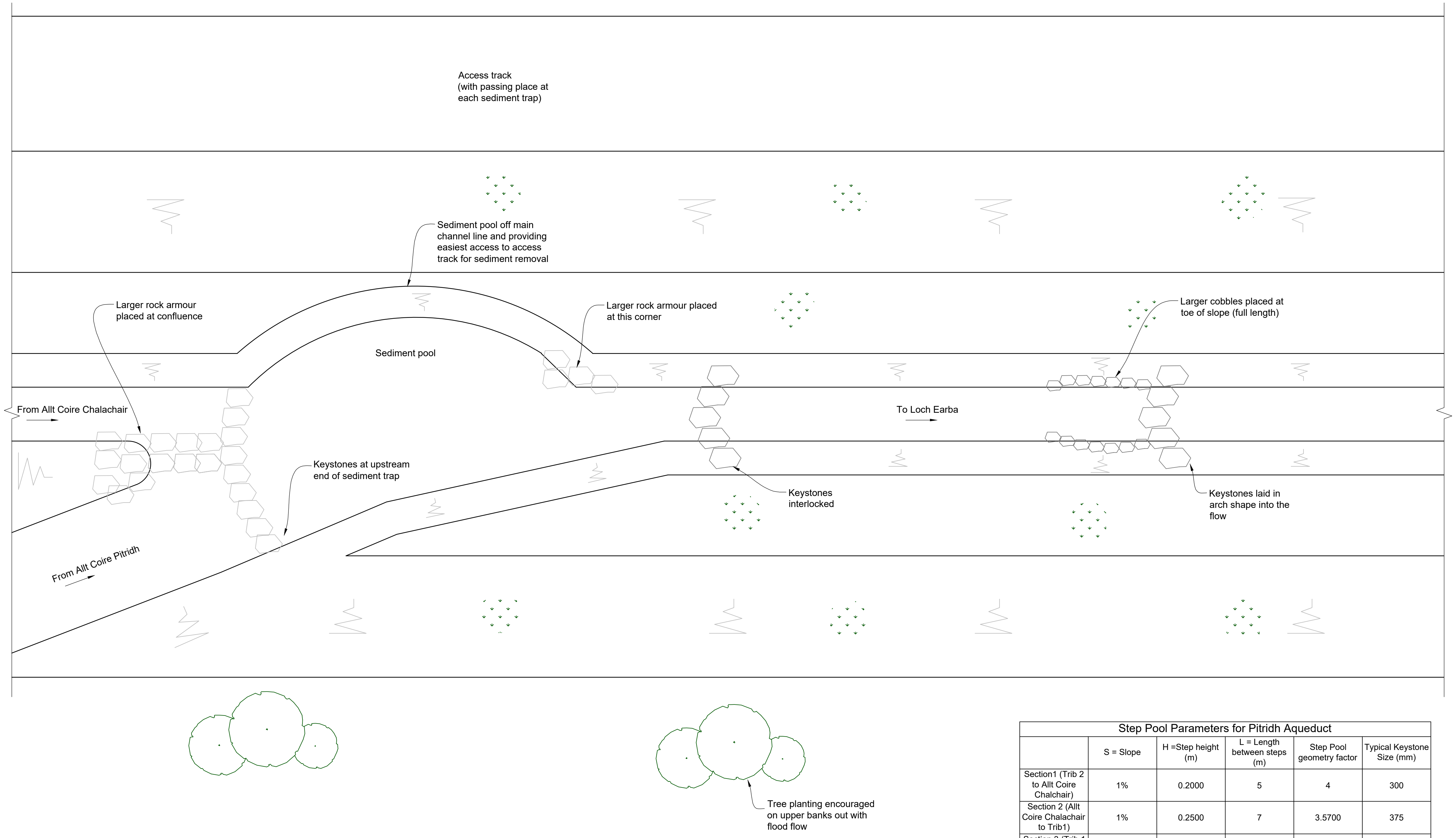
IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).
2. All dimensions are in millimeters unless otherwise noted.
3. Please refer to CEMP for details of environmental protection measures (e.g. temporary erosion control, sediment traps, settlement lagoons, silt curtains). The works would be supervised by an Environmental Clerk of Works.
4. For proposed structure of sediment management plan refer to geomorphology report.
5. Climate change uplift for peak flows calculated in accordance with "SEPA's Climate change allowance for flood risk assessment in land use planning Version 5".
6. Resting pools shown indicatively on aqueduct plan. Final location to be agreed with an experienced fish ecologist at the detailed design stage.
7. Aqueduct channel substrates would be formed using natural sediments local to the system, to provide a well-graded mix of sediment appropriate to the energy regime of a stepped pool channel.
8. CCTV coverage at the confluence of existing burn and channel would will provide real time monitoring of flow and sediment conditions.

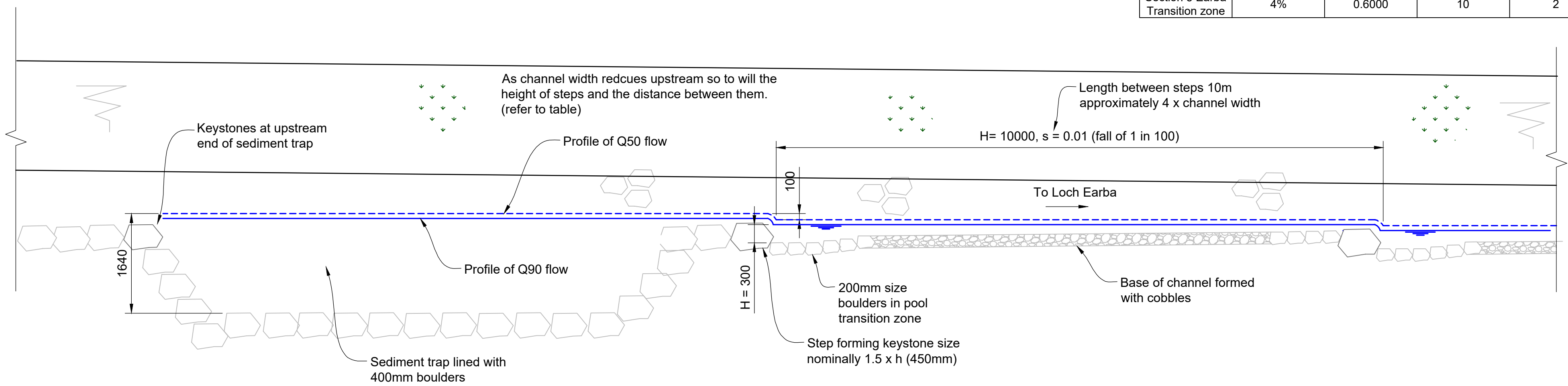


Plan on confluence of Allt Coire Pitridh to Pitridh Aqueduct

1:100 @ A3

Step Pool Parameters for Pitridh Aqueduct

	S = Slope	H =Step height (m)	L = Length between steps (m)	Step Pool geometry factor	Typical Keystone Size (mm)
Section1 (Trib 2 to Allt Coire Chalchair)	1%	0.2000	5	4	300
Section 2 (Allt Coire Chalachair to Trib1)	1%	0.2500	7	3.5700	375
Section 3 (Trib 1 to Allt Coire Pitridh)	1%	0.2500	7	3.570	375
Section 4 (Allt Coire Pitridh to Loch Earba)	1%	0.3000	10	3	450
Section 5 Earba Transition zone	4%	0.6000	10	2	600



0 1.25m 2.5m

Section on confluence of Allt Coire Pitridh to Pitridh Aqueduct

1:100 @ A3

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P1	13.11.24	MH	CAR LICENCE SUBMISSION	DT	GMcG

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TITLE

PITRIDH AQUEDUCT DETAILS - SHEET 3 FIGURE 2.21.3

SIZE A3 | SCALE AT A3 1:100 | STATUS PLANNING

DRAWING NUMBER EAR/GEL/297 | REVISION P1

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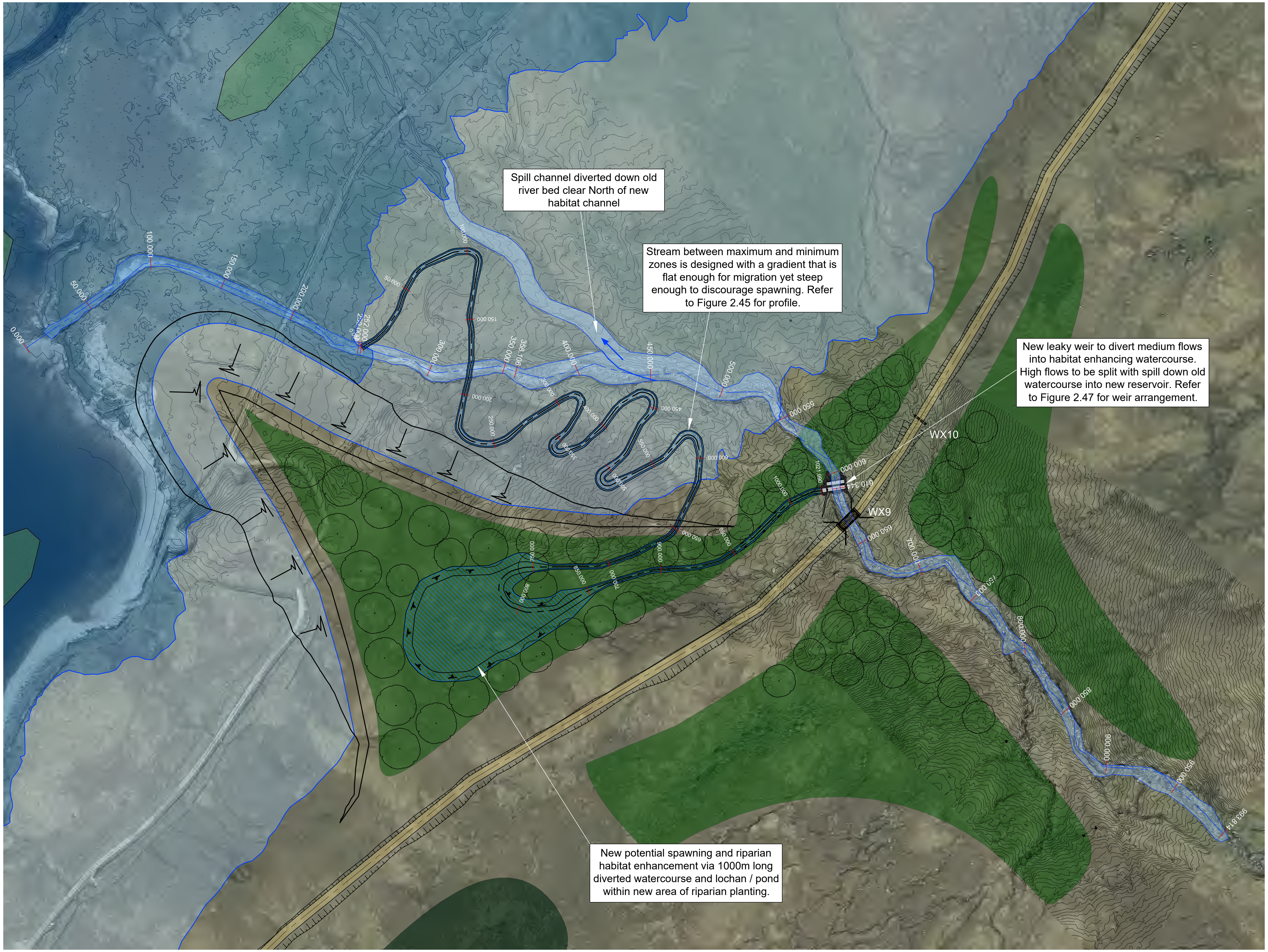
D PROPOSED MOY BURN DESIGNS

North



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Plan

Moy Burn Spawning Habitat Enhancement

1:1250 @ A1, 1:2500 @ A3

0 62.5m 125m

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IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).
2. All chainages are in metres.

LEGEND

- Existing Stream
- New Stream and Lochan
- New Tree Planting - Riparian Mix
- New Tree Planting - Upland Mix
- New Tree
- +376m Maximum Inundation Level
- +355m Minimum Water Level
- Promontory
- PSH Track
- Floating Habitat

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P2	13.11.24	MH	CAR LICENCE SUBMISSION	DT	GMcG
P1	29.08.24	MH	PRELIMINARY	DT	GMcG

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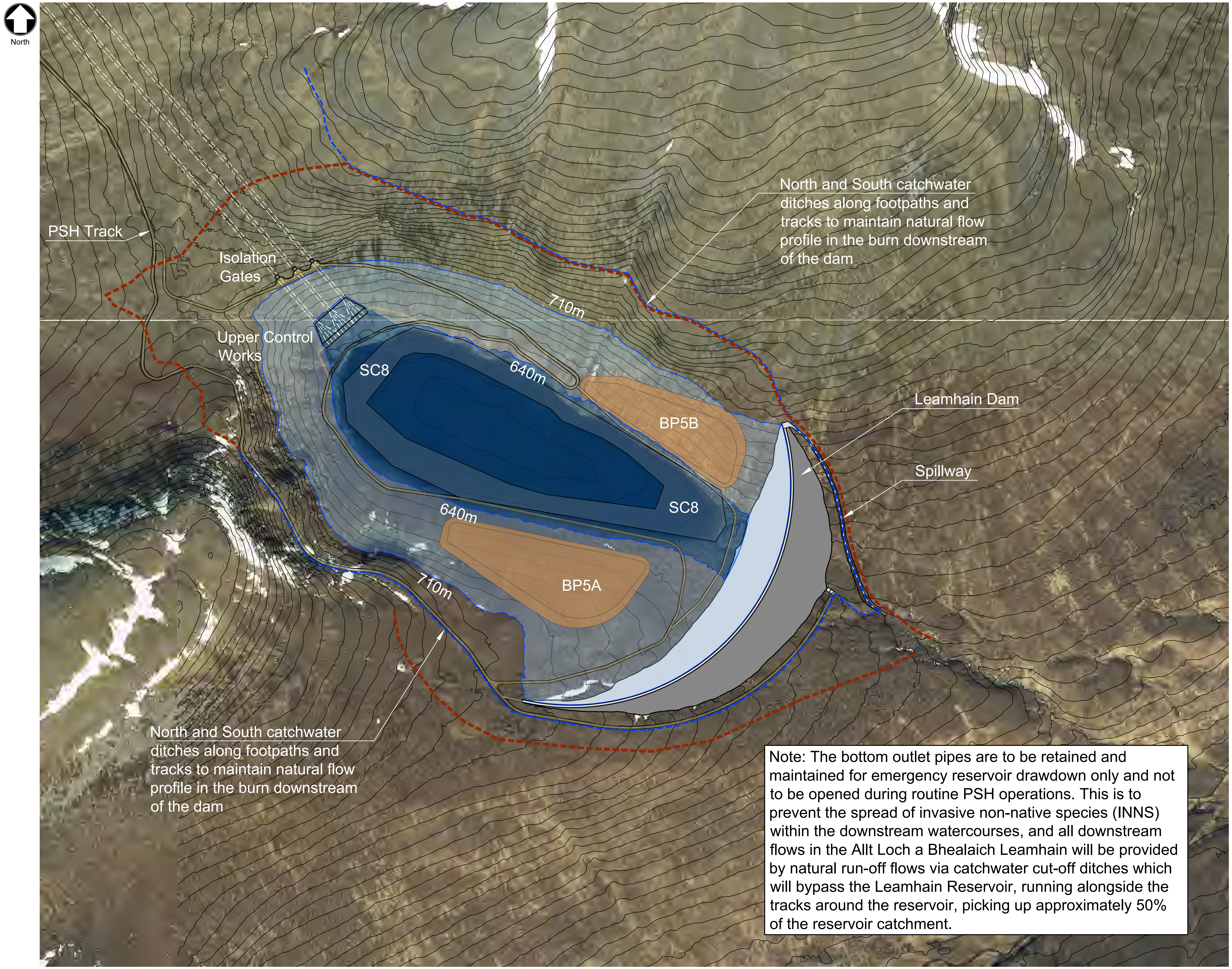
TITLE

MOY BURN
HABITAT ENHANCEMENT WORKS
AREA PLAN - FIGURE 2.44.1

SIZE A3 | SCALE AT A3 1:2500 | STATUS PRELIMINARY

DRAWING NUMBER EAR/GEL/240 | REVISION P2

E PROPOSED LEAMHAIN RESERVOIR DESIGN



Note: The bottom outlet pipes are to be retained and maintained for emergency reservoir drawdown only and not to be opened during routine PSH operations. This is to prevent the spread of invasive non-native species (INNS) within the downstream watercourses, and all downstream flows in the Allt Loch a Bhealaich Leamhain will be provided by natural run-off flows via catchwater cut-off ditches which will bypass the Leamhain Reservoir, running alongside the tracks around the reservoir, picking up approximately 50% of the reservoir catchment.

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Plan

1:10,000 @ A3

0 250m 500m

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IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).

LEGEND

- +710m Maximum Inundation Level
- +640m Minimum Water Level
- Dam Footprint
- Tunnel
- Intake
- Isolation Gate House
- Estate Track / Footpath
- Cut-off Ditch
- Borrow Pit
- Compound (SC8)

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P2	13.11.24	MH	CAR LICENCE SUBMISSION	DT	GMcG
P1	26.01.23	MH	FOR PLANNING	DT	GMcG

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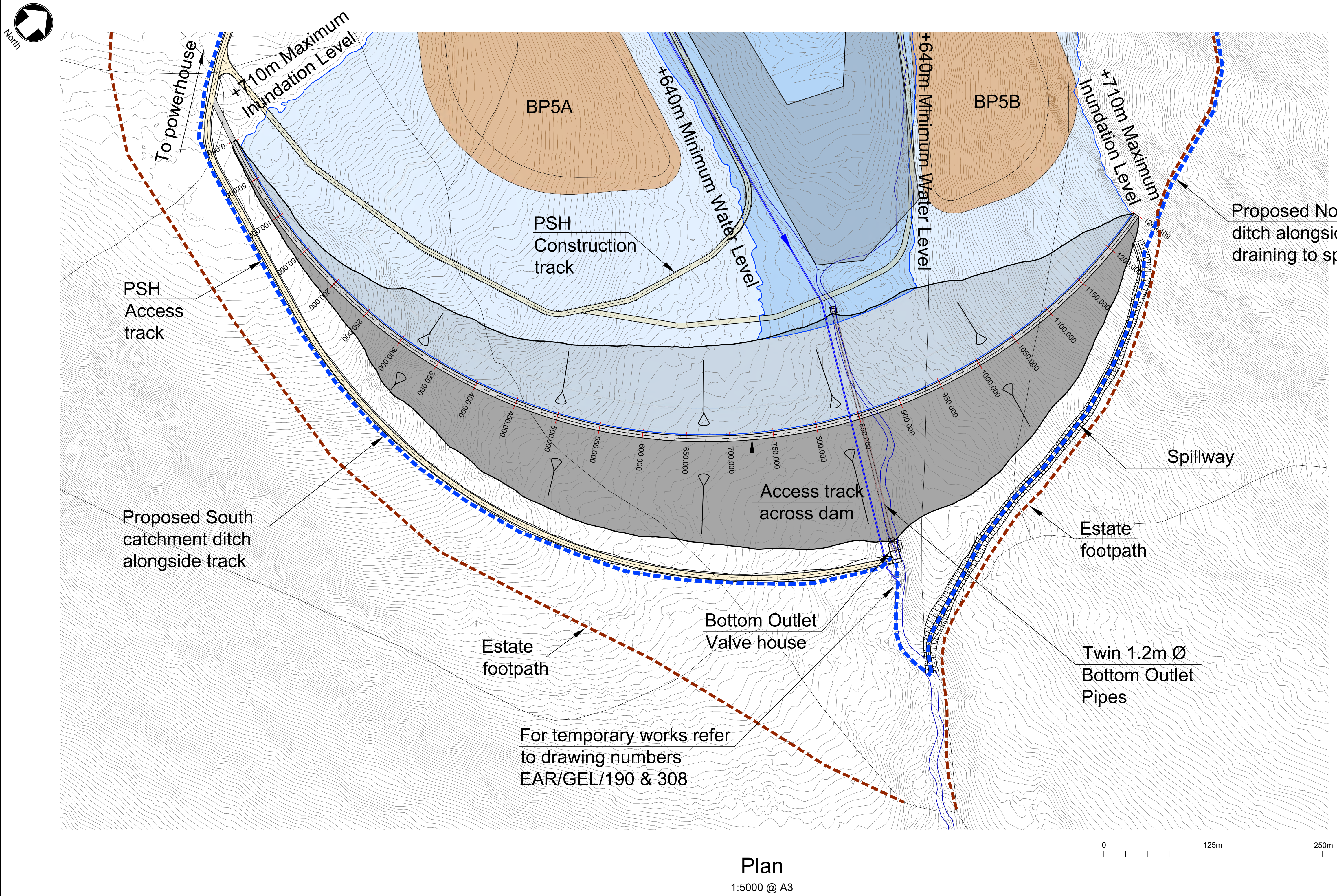
TITLE

UPPER LEAMHAIN RESERVOIR PLAN VIEW FIGURE 2.4

SIZE	SCALE AT A3	STATUS
A3	1:10,000	PLANNING

DRAWING NUMBER	REVISION
EAR/GEL/301	P2



Plan

1:5000 @ A3

IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).

LEGEND

- +710m Maximum Inundation Level
- +640m Minimum Water Level
- Dam Footprint
- Estate Track / Footpath
- Cut-off ditch
- Borrow Pit
- Compound

REV	DATE	DRAWN	NOTES	CHK'D	APP'D
P2	13.11.24	MH	CAR LICENCE SUBMISSION	DT	GMcG
P1	03.05.24	MH	CAR LICENCE SUBMISSION	DT	GMcG

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PROJECT

PROPOSED EARBA PSH

TITLE

LEAMHAIN DAM LAYOUT PLAN FIGURE 2.5.1

SIZE	SCALE AT A3	STATUS
A3	1:5000	PLANNING

DRAWING NUMBER	REVISION
EAR/GEL/303	P2

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F PROPOSED SHIOS DAM DESIGN

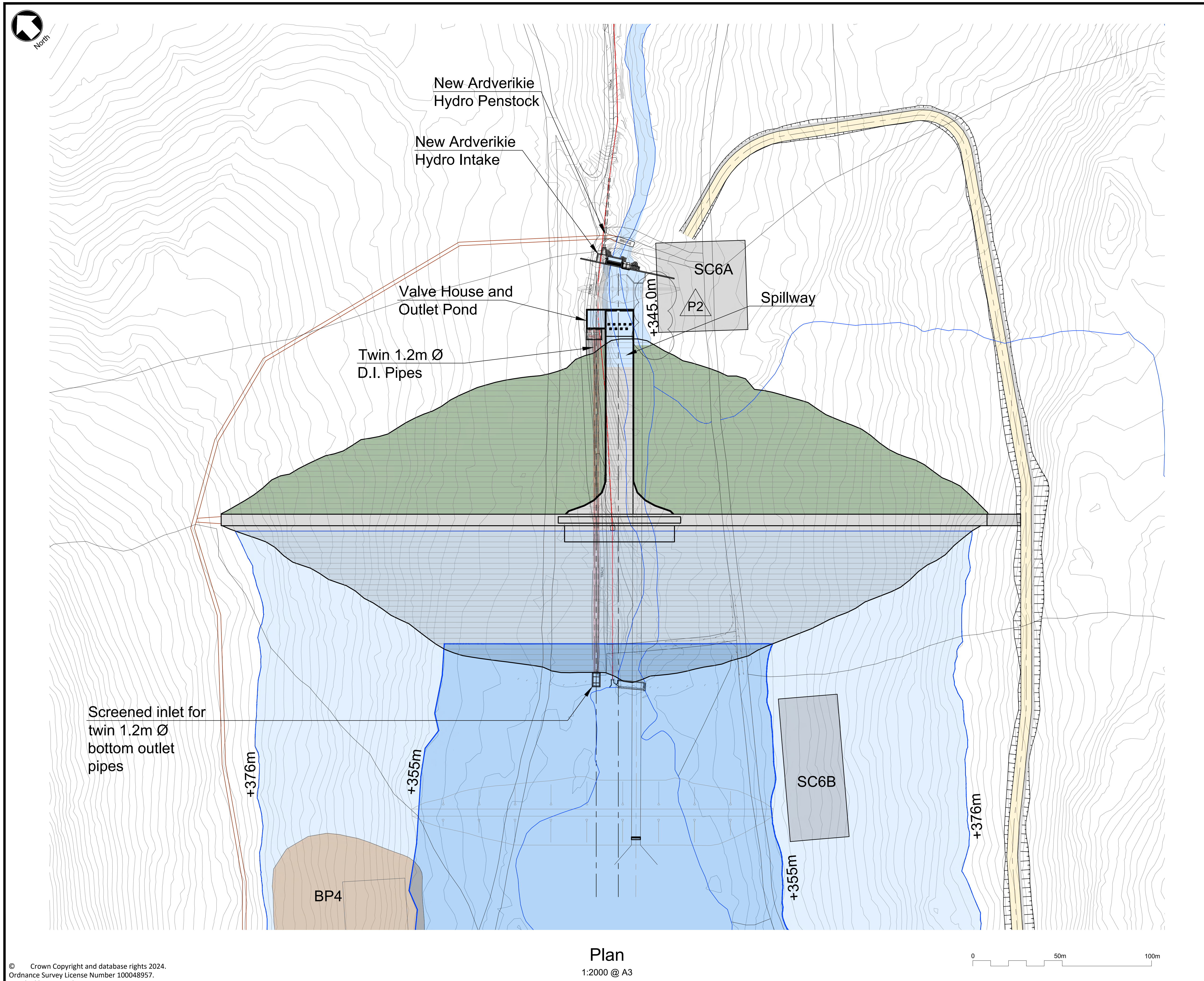
IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).

LEGEND

- +376m Maximum Inundation Level
- +355m Minimum Water Level
- +345.5m Ardverikie Hydro Intake Inundation Level
- Dam Footprint
- Estate Track / Footpath
- PSH Track
- Borrow Pit
- Compound



Plan

1:2000 @ A3

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REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P2	13.11.24	MH	CAR LICENCE SUBMISSION	DT	GMcG
P1	26.04.24	MH	CAR LICENCE SUBMISSION	DT	GMcG

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EARBA PSH

TITLE
SHIOS DAM
LAYOUT PLAN
FIGURE 2.7.1

SIZE	SCALE AT A3	STATUS
A3	1:2000	PLANNING

DRAWING NUMBER	REVISION
EAR/GEL/204	P2

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G OUTLINE SPECIFICATIONS FOR CHANNEL DESIGN

To support the detailed design of the diversion and compensatory habitat channels, the table below provides outline specifications for step-pool and cascade channel design. This has been compiled on the basis of draft guidance provided by SEPA.

Feature	Step-Pool	Cascade
Cross-section	Two-stage channel profile to focus lower flows (reducing the risk of lower flows being overly shallow or even 'lost' through coarse substrates).	Central low point to focus flows and minimise bank erosion.
Conditions	Slopes 0.005 - 0.075 m/m; moderately confined flows; low sinuosity.	Slopes >0.075 m/m; highly confined flows; low sinuosity.
Flow types	Moderately high flows alternating between faster flow over steps and slower flow through pools to dissipate excess energy.	Turbulent flows tumbling over steps, around boulders, and through pools to dissipate very high energy.
Long profile	Regularly spaced keystone boulders interlocked with smaller boulders / cobble (to fill voids), with boulders on upstream face, to form steps spanning channel width; separated by pools that may contain gravel.	Series of very closely spaced steps formed by immobile, interlocked keystone boulders, with smaller boulders & cobbles in between.
Keystone Size	Large boulders, oversized compared to an equivalent natural channel. Upstream source available.	Larger boulders (oversized to be immobile during design floods). Upstream source available.
Keystone arrangement / embedment	Step formed as a U or V shape with the apex pointing upstream to focus flow over the step centre, with forces pushing the boulders together during high flows and concentrating flows over the step centre to minimise bank scour. This flow concentration can be further enhanced with the central keystones being set slightly lower than those at the banks. >1 layer of interlocked keystones so that the base of the step is sufficiently below bed level to prevent scour undermining the keystones. Extend step into bank to prevent lateral scour around the keystones.	>1 layer of keystones interlocked to ensure step lower than bed level. Extend keystones into banking to prevent lateral scour around keystones.
Step height	Governed by channel slope, keystone size / embedment / buildability / fish passage. Indicative 1.0 - 1.5 times particle size.	Governed by size of keystones / embedment / buildability / fish passage.
Step spacing	Step spacing determines pool length and in natural step-pools is linked to channel size and gradient. Typically spaced every 1 to 4 channel widths and tend to be closer spaced the steeper the channel.	Frequent step sequence with regularity likely required.

Feature	Step-Pool	Cascade
Pools	Step-pool geometry ratio >2.0 to maximise energy dissipation. Pools typically 20% wider than the steps at their widest point. Pool would normally be deepest and widest at its upstream end, shallowing and narrowing toward the downstream end due to the reverse gradient of the bed.	Small pools that might not span full width. Reverse gradient between steps.
Bed materials	Natural supply from upstream. Mobile sediments (cobble / gravel) may accumulate in pools.	Natural supply from upstream. Mobile sediments (cobble / gravel) may accumulate in pools.
Bank materials	Boulder reinforcement along base, with vegetated earth banks above.	Boulder reinforced banks, with vegetated earth banktops.
Riparian vegetation	Tree planting where possible to provide shade, food source & woody material. Trees to be excluded where maintenance access required.	
Potential Habitat Enhancements	Backwater pools, berms, woody structures, berms, spawning gravel placement, vegetation enhancements, floodplain wetlands.	Side pools
Maintenance	Clearance of excess sediments & woody debris where it compromises functioning / structures within channel	
Natural Example		
Long Profile