EARBA STORAGE

A GILKES ENERGY COMPANY

Earba Pumped Storage Hydro Scheme

EIA Report

Appendix 6.2: Hydromorphology Report

February 2024

Earba Pumped Hydro Scheme
Hydromorphological Appraisal

December 2023

CONTROL SHEET

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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 Hydropower Scheme (PHS) on Ardverikie Estate, Kinloch Laggan. This hydromorphological assessment is required to support the Planning and Controlled Activities Regulations (CAR) applications for the development, following client consultation with the Scottish Environment Protection Agency (SEPA). The report will be included as a Technical Appendix to the Environmental Impact Assessment Report which is in preparation at the time of writing.

1.2 Scope of Report

The proposed PHS development will operate by transferring water between two existing loch systems, the capacity of which would be enhanced through the formation of dams. The lower reservoir will be formed at Loch Earba (*Lochan na h-Earba*) and the upper reservoir will 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 four key watercourse systems which have been identified for assessment through SEPA consultation:

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

The impacts to the physical processes will be assessed in relation to proposed channel diversions (Pitridh and Chlachair Burns) and proposed upstream impoundment (Allt Labrach and Leamhain Outfall).

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 has not extended to include topographic survey, sediment sampling, fluvial audit, sediment modelling / budgeting. Reservoir shoreline impacts are not included within the current scope.

The impact assessment focuses on the likely effects of the proposed diversions and impoundments on channel morphology 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 will be very low or negligible.

1.3 Report Usage

The information and recommendations contained within this report have been prepared in the specific context stated above and should not be utilised in any other context without prior written permission from EnviroCentre Limited.

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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*.

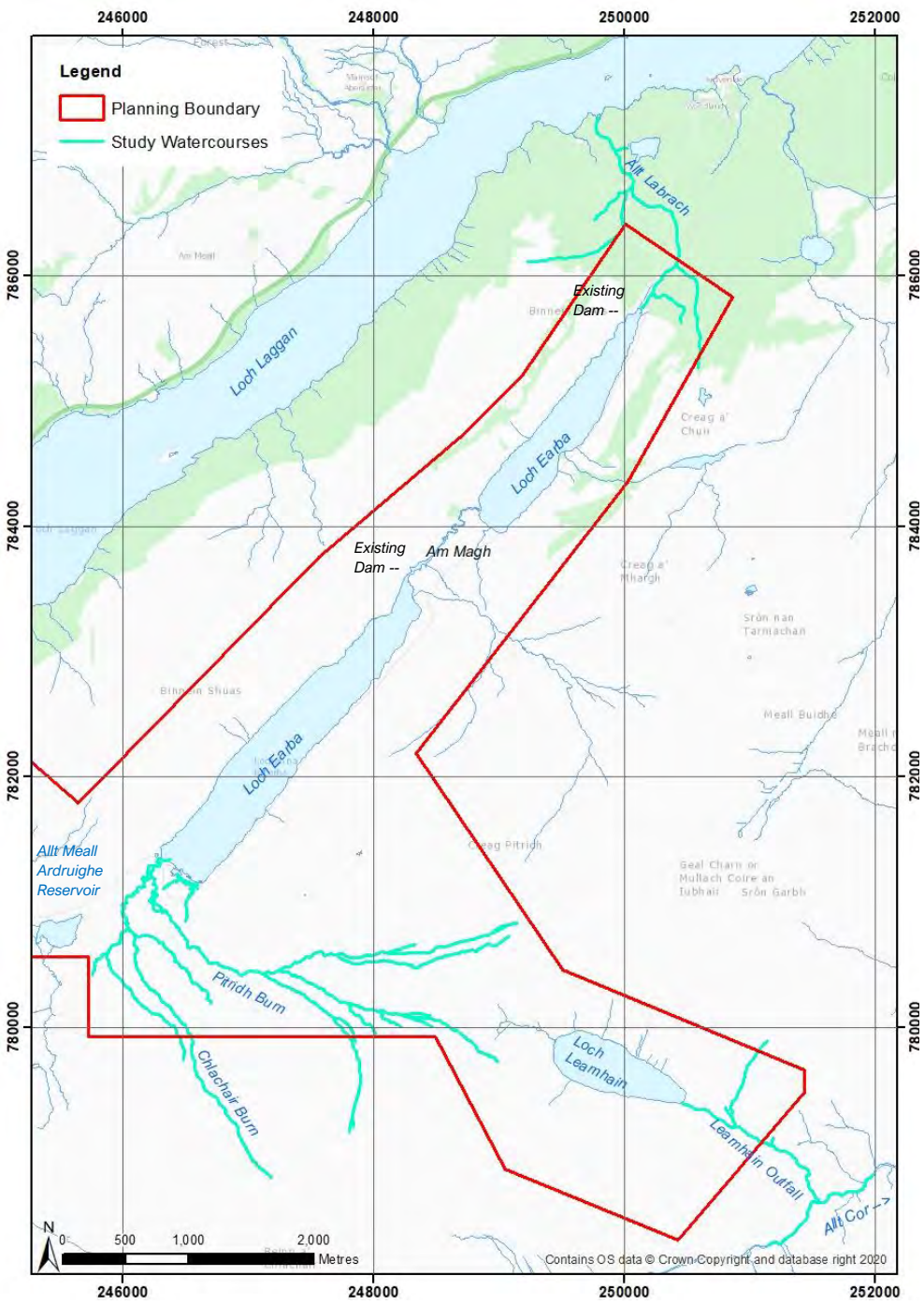


Figure 2-1: Proposed development site and study watercourses

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).

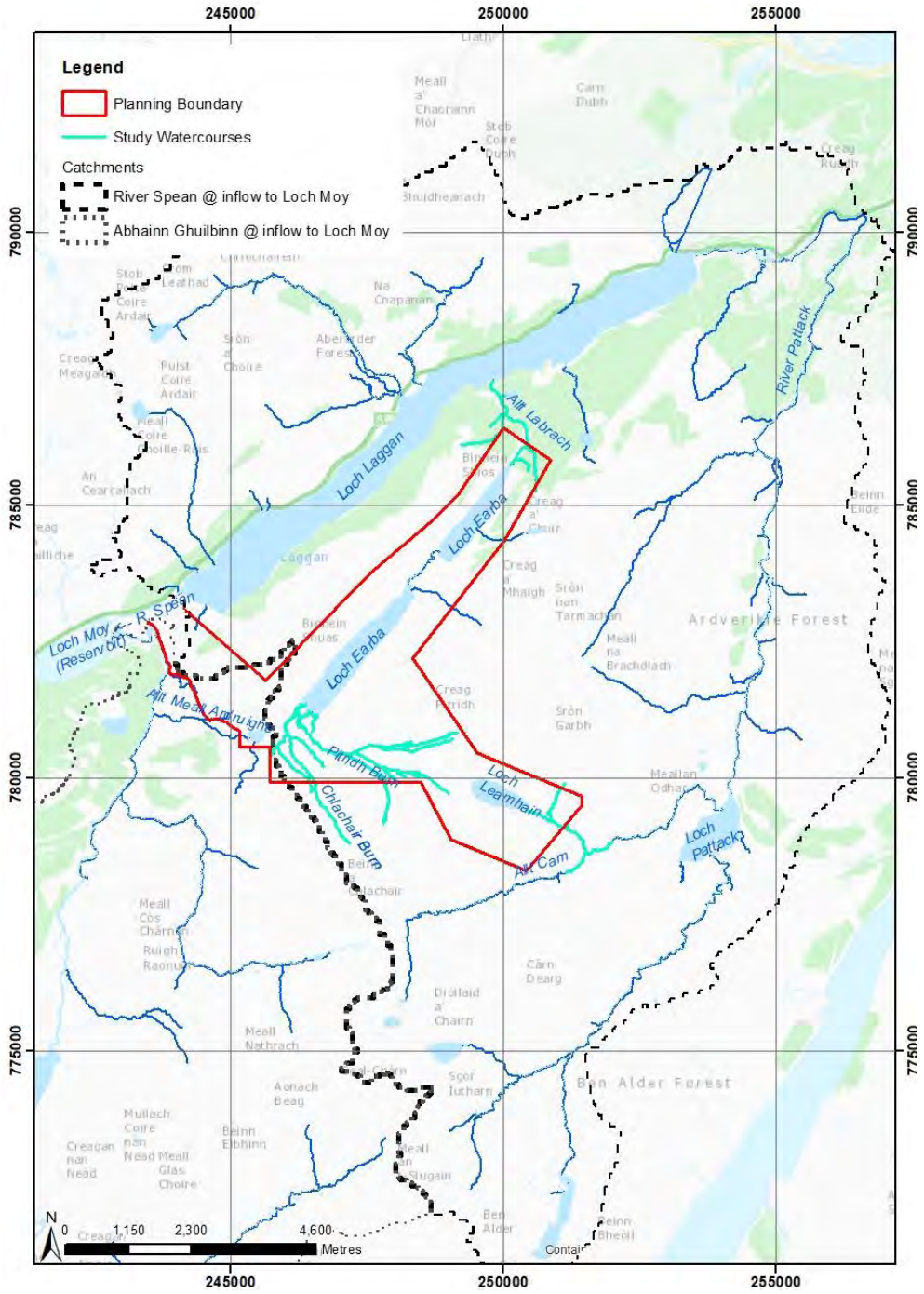


Figure 2-2: Wider catchment context

2.2 Proposed Development

At the time of writing this report, the proposed generating capacity of the Earba PHS will be up to 1,800 MW. The scheme will involve the use of new dams, to create reservoirs from existing lochs. There will be an upper reservoir on Loch Leamhain and a lower reservoir on Loch Earba.

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 636m AOD to a maximum level of 710m AOD.

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. Earth or 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.

The reservoirs would be connected by a tunnel system, including a surge shaft on the west ridge of Creag Pitridh. A powerhouse will 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 is required to intercept several tributaries and divert flows directly into Loch Earba at its upstream (west) end. This will avoid ponding on the upstream side of the dam. An aqueduct is planned (understood to be likely to be buried), which will function to drain residual water from the area to the west of the dam into the existing reservoir further to the west. This reservoir is at the head of the Allt Meall Ardruighe burn, 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 Allt Meall Ardruighe reservoir is operated by Ardverikie Estate (controlled reservoir reference RES/R/1128065) for amenity purposes.

2.3 Site Walkover

A 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 channel were moderate and were observed to recede slightly over the course of the day.

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 walkover 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 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).

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 Watercourse Overview

2.5.1 Pitridh and Chlachair Burns

The Pitridh and Chlachair Burns (proposed for diversion) 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.

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

2.5.2 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 may be 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.

2.5.3 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 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

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

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.

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 2-3. These have been generated through spatial analysis of digital terrain model data (LiDAR / Ordnance Survey Terrain 50) using ArcMap GIS software with 3D 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. Only 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 highly 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.

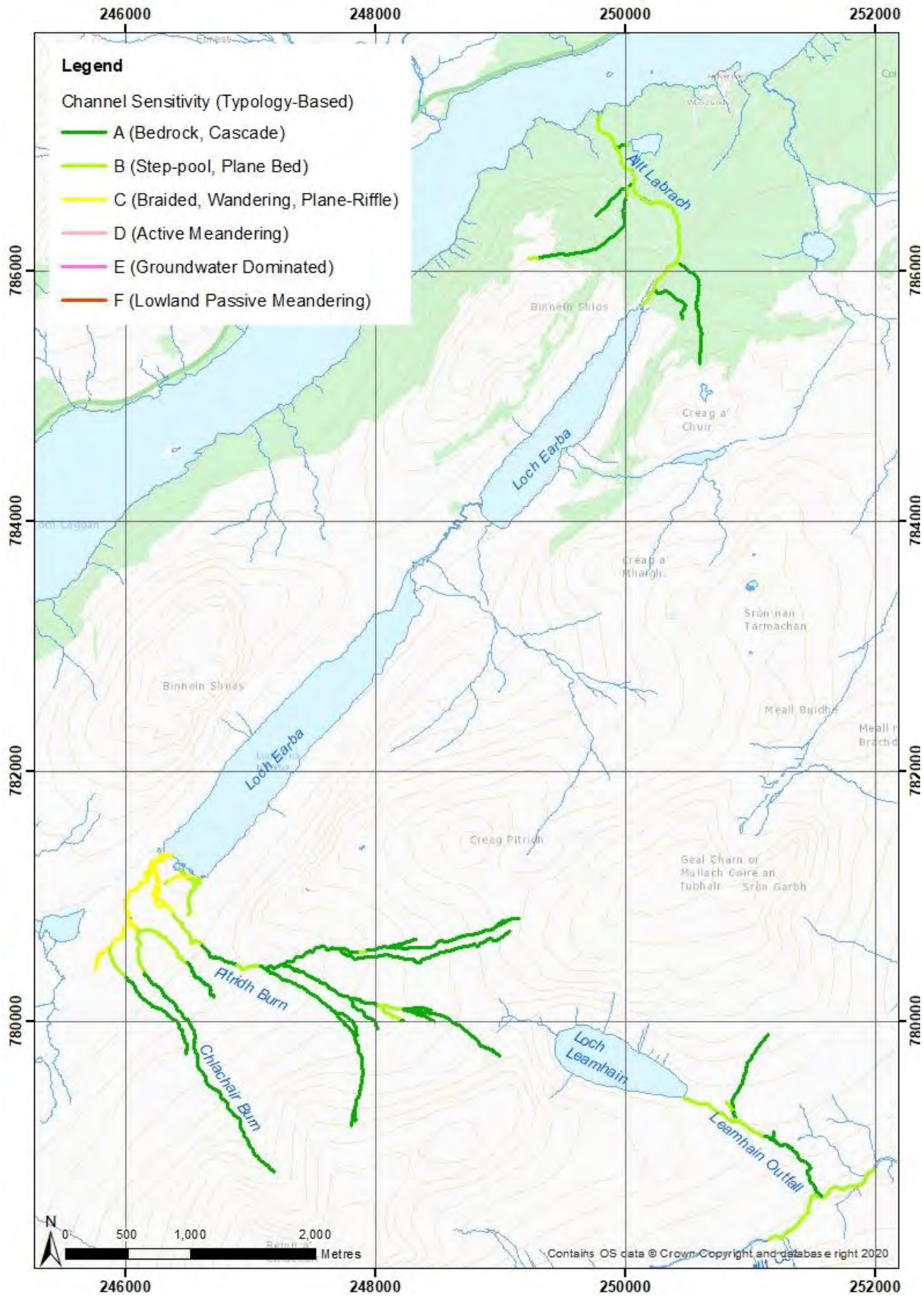


Figure 2-3: River typology

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 will 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 will 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.

3.2 Impacted Reaches

The reaches impacted by the proposed PSH are predominantly downstream of the proposed dams and diversion channel and are shown on Figure 3-1. 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 will be most impacted but that the impacts would be anticipated to diminish downstream (as flows and sediments are recruited from lateral sources) and will 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	
Diversion: - mainstem Pitridh / Chlachair Burns	81	622	2133	**2,836**
- minor channels / tributaries	*172*	*4,086*	*620*	*2,095*
Allt Labrach	-	2,027	-	**2,027**
Leamhain Outfall	761	757	-	**1,518**

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 mitigated and may be considered acceptable in the context of high energy system with high background levels of disturbance during storm conditions.

Over the longer term (operational phase) one of the most significant long-term impacts of impoundment can be 'sediment starvation' in downstream channels, associated with 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 will 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 energy of water is greater than that of the receiving channel, due to increased velocities and erosive capacity, requiring careful design and construction.

Overall, the operational phase of the scheme will 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).

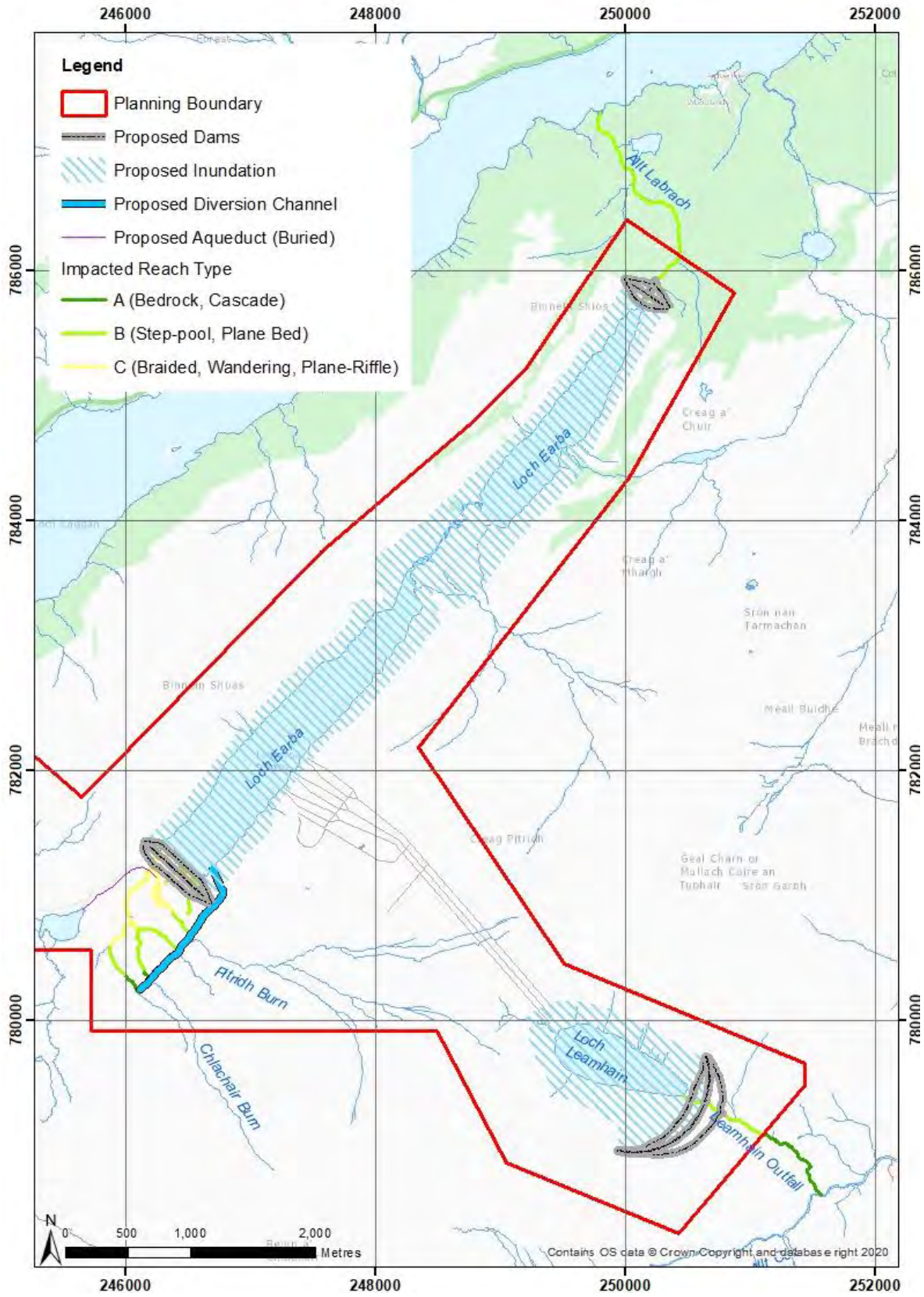


Figure 3-1: Potentially impacted reaches of study watercourses

3.4 Channel Diversion

The proposed channel diversion is 1,300m in length, and intercepts flows from the Pitridh and Chlachair Burns, together with a several unnamed tributaries and unmapped overland flow routes, which can be seen on the UAV imagery and representative photos in Figure 3-2.

Upstream of the proposed diversion, 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 diversion 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 diversion channel is estimated to be 2,836m.

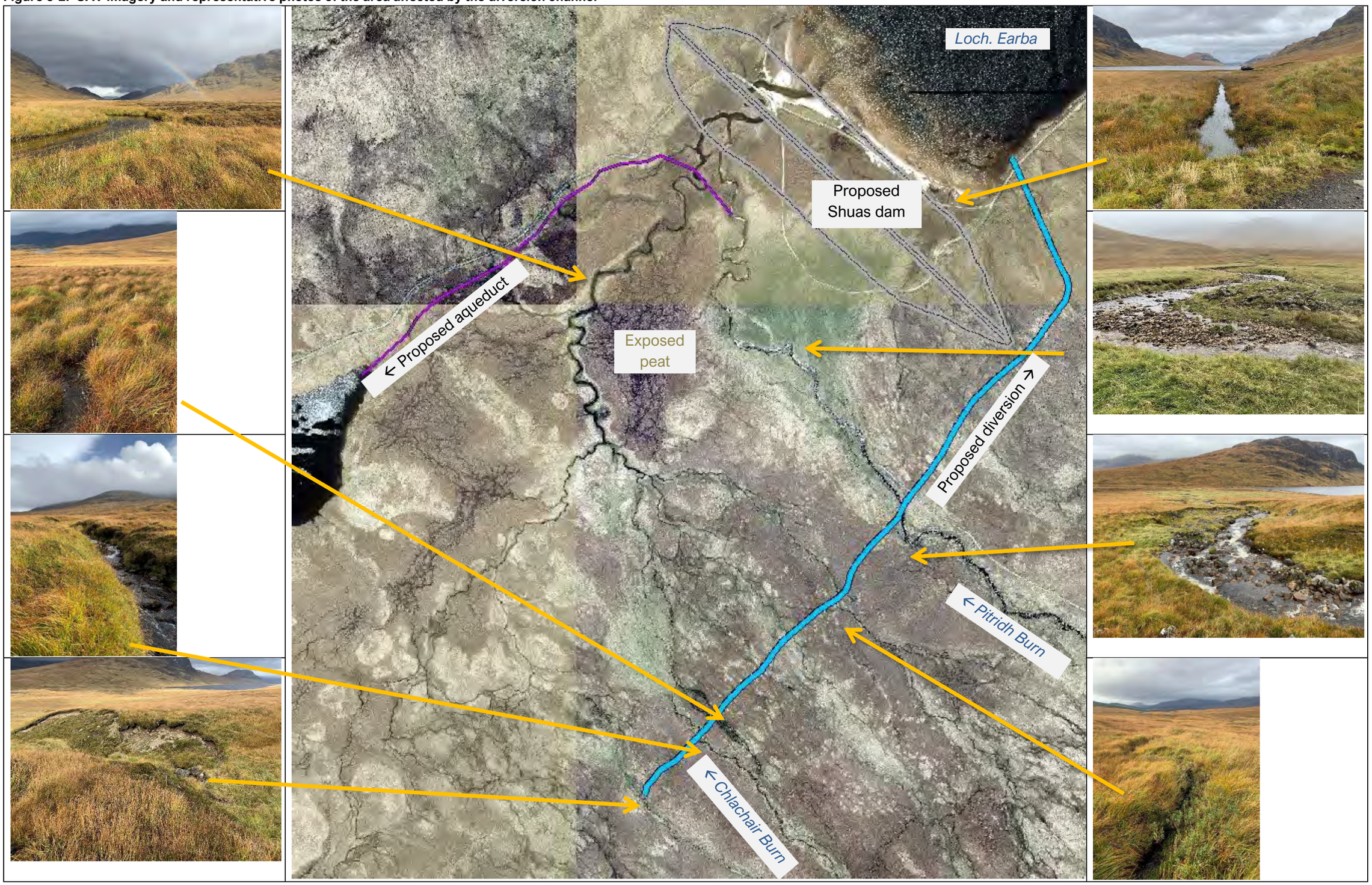
These reaches will be affected by the type of impacts described above for impoundment, in the sense that the diversion channel will act as a barrier to sediment supply from upstream; although the significant volume of sediments currently stored in the 'sediment sink' in this area will remain available for 're-working' (albeit under a reduced flow regime). The loss of sediments through the natural channel into Loch Earba will be prevented by the dam, although a small proportion of the losses may be transferred to the existing reservoir to the west via the proposed aqueduct. It is anticipated that sediment deposition will occur within the diversion channel, which may require active management.

Unaffected tributary sources, groundwater baseflow, precipitation and piped compensatory flows through the diversion channel will maintain a reasonable baseflow through the channels, with higher 'channel forming' flows (which drive morphological processes and dictate channel dimensions) being more significantly limited. It would be anticipated that stream power (the ability of the channel to mobilise sediments) will be reduced over time, and the channel profile would start to decrease in dimension due to sediment deposition, vegetation growth and soil formation on channel margins.

The footprint of the dam and inundation area will 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. Aqueduct formation has the potential to affect water levels in the lower reaches of the system, depending on the design of the hydraulic controls at the inlet; and this may in turn affect water velocities and morphological processes locally. This would also have potential to impact associated wetland dynamics and induce a transition in wetland typology and habitats.

In terms of the proposed diversion channel itself, the upper 1,100m of the channel will have a typical bed slope of 0.0127m/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, temporary 200m reach on the approach to Loch Earba (as shown on Drawing EAR/GEL/292, Appendix C), which is to be re-profiled to a shallower grade following construction, will have a typical slope of 0.102m/m. In a natural channel, this would align with a Type A (cascade) channel typology, where fast and turbulent / supercritical flows may be anticipated.

Figure 3-2: UAV imagery and representative photos of the area affected by the diversion channel



3.5 Associated Impacts

WFD waterbody classifications (see section 2.6) will be affected by the proposed scheme. While quantification of impact on status (including Morphological Impact Assessment. System, MiMAS) is beyond the scope of the current appraisal, it is anticipated that the proposed channel diversion 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 the 'Shuas Dam').

There will be a requirement to demonstrate that the proposed impacts on the classification of the Pitridh Burn and Allt Labrach Waterbodies are justifiable, in the context of national benefit of large scale renewables. This will be assessed across multiple quality factors (including hydromorphology, hydrology and ecology) and will 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 will also have the potential to impact on morphology, at a localised level, if not subject to careful design, for example through the instigation of scouring or through impediment to sediment transport. It is assumed that these impacts will be assessed and mitigated separately through EIA and CAR licencing processes.

Flow diversion through the reservoir to the west via the aqueduct will 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 will attenuate the transmission of flows downstream.

The scheme during operation may have 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 RECOMMENDATIONS

The following outline recommendations are given to minimise / offset the impacts of the proposed PHS on hydromorphology through the design, construction and operation of the scheme:

1. SEPA should be consulted at an early stage to explore the feasibility and any further requirements for waterbody status derogation and CAR Authorisation (Complex Licence).

2. Construction impacts, particularly the release of sediments into the system (anticipated to be relatively short-lived) should 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 works should be supervised by an Environmental Clerk of Works.

3. Any outflows from the proposed dams, designed to return water to the channel downstream, should be carefully designed to dissipate energy and mitigate erosion in the vicinity of the discharge point into the receiving watercourse.

4. The channel diversion should be designed and constructed with consideration of local channel conditions within each tributary channel and be adapted accordingly to minimise abrupt transitions in approach angles / curvature and bed slope which may induce instability. Hydraulic modelling may be useful to support the detailed designs of the diversion channel to ensure suitability of channel dimensions and slopes in relation to, for instance, flow conveyance capacity and stream power.

5. With the diversion channel potentially being designed to accommodate a 1 in 1,000 year + climate change design flood, it is advised that a concave or two-stage channel profile is considered to focus lower flows (reducing the risk of lower flows being overly shallow or even 'lost' through coarse substrates). To enable the diversion channel to better mimic natural typology, the engineered channel bed could include a series of low profile boulder steps at a height and frequency appropriate to the wider channel grade.

6. As far as practicable and safe, the channel maintenance regime should encourage continued sediment transport processes and the formation of morphological features. 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). As such, the diversionary channel may be considered an opportunity to create habitat to compensate for some of the habitat losses incurred elsewhere.

7. Where sediments are removed from the diversion channel, they should be carefully reintroduced to the alluvial fan area (or potentially into other reaches downstream of impoundments that have been identified as being suitable for sediment re-introduction), following 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 placement, timing, volumes and frequency of sediment re-introduction.

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

8. As indicated in the available designs for the diversion channel, the provision of compensatory flows through the wall of the diversion channel would partially mitigate the reduction in flows and sediments through to the alluvial fan / plain.

9. The aqueduct should be designed to avoid excessive backwater or drawdown effects from the Pitridh / Chlachair Burns and associated wetlands.

10. To mitigate the flow regime modification through the Earba and Leamhain dams, the provision of compensatory / freshet flows should be considered, with input from SEPA and NatureScot. It is understood that compensatory flows are not a requirement on the existing hydro scheme, and so there is potential to provide a relative betterment to the current flow regime of the Allt Labrach, benefitting both hydromorphology and river habitats.

11. Annual monitoring of channel sediments and trapping of sediments behind the dams is recommended, along with the preparation of a sediment management plan, with consideration given to the potential need to remove trapped sediments within the reservoirs, which would be carefully re-introduced downstream, as appropriate.

12. As detailed applications are progressed, there may be a potential requirement arising to undertake more detailed hydromorphological assessments, e.g. sediment budget to quantify sediment transport and supply rates, in order to predict the likely effect on morphology and associated aquatic ecology, and to support sediment management / mitigation plans.

5 CONCLUSIONS

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 four 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 channel diversion on the Pitridh and Chlachair Burns, and of the proposed impoundments on the Allt Labrach and Leamhain Outfall, have been appraised.

The steep upper reaches of the tributaries proposed for diversion will be unaffected by the scheme, with the most significant impacts being in the immediate vicinity and downstream of the diversion channel. Here, 'Type C' river typologies will be impacted by reduced sediment supply as well as flows. Over time, it is anticipated that the affected reaches will adjust to reduced flows (particularly less significant channel-forming flows) and become smaller in profile. This will be mitigated, for instance through the provision of compensatory flows and through the re-introduction of sediments removed from the diversion channel as part of a routine maintenance regime.

The relative impact of the dam construction on the Allt Labrach will be low in the context that it is already artificially impounded for hydropower purposes. The proposed dam on the Leamhain will enhance the existing natural impoundment. Both watercourses are high energy systems which are relatively resistant to physical change, in hydromorphological terms. The effects will diminish in the downstream direction, and the lengths of the affected reach are also physically limited by the presence of lochs / reservoirs downstream.

In terms of next steps, it is recommended that SEPA are consulted in terms of the mitigating and/or derogating the impacts on waterbody status, and to explore requirements for any further information to support the CAR licence for the development.

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	

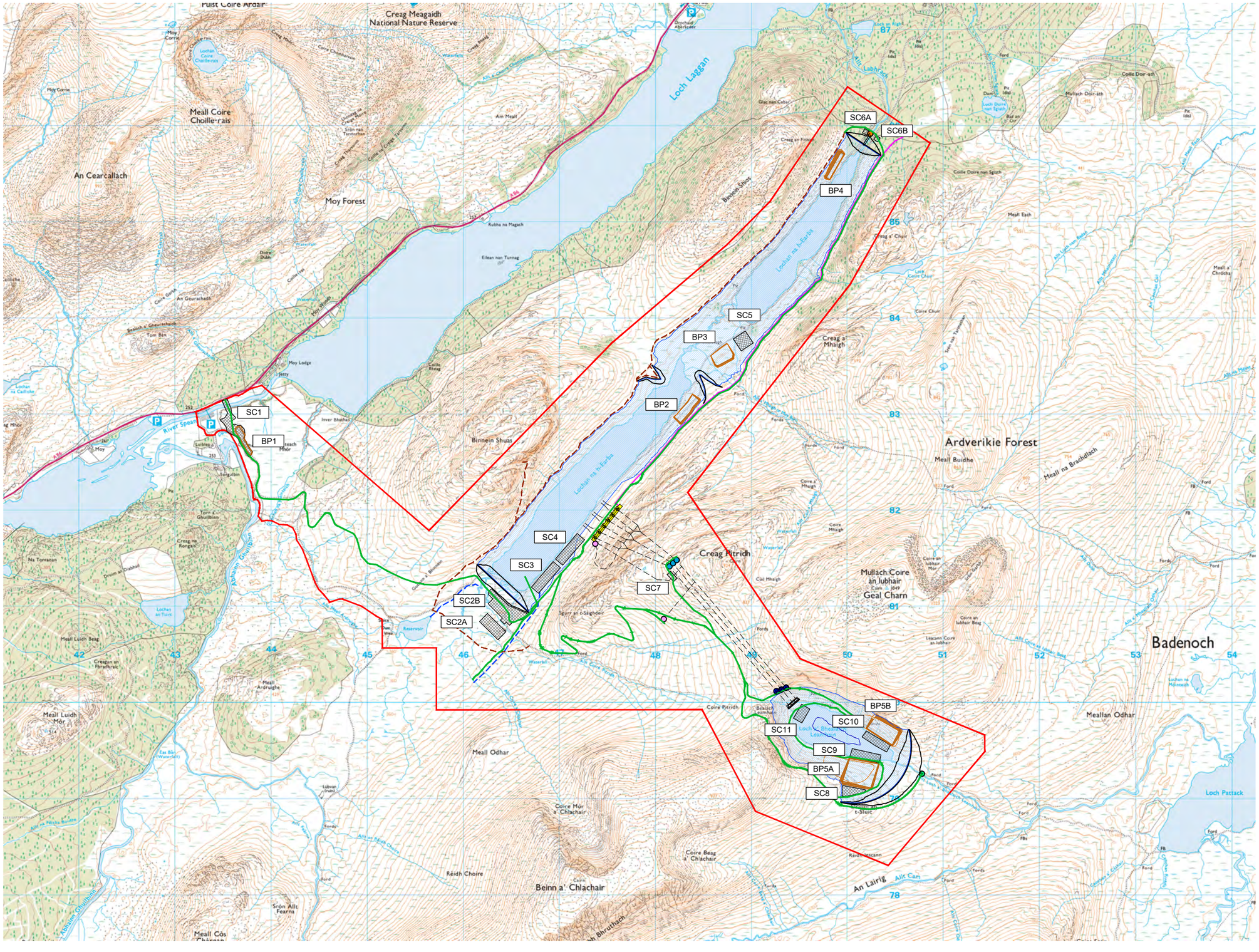
7. Existing Dam at Loch Earba Outflow to Allt Labrach	
8. Allt Labrach Upper Reaches	
9. Allt Labrach Lower Reaches	

10. Leamhain Outfall (Natural Control)	
11. Leamhain Outfall Upper Reaches	
12. Leamhain Outfall Middle Reaches	

13. Leamhain Outfall Lower Reaches (fore) and confluence with Allt Cam (rear)	

B PROPOSED SCHEME ARRANGEMENT

North



Plan
1:20,000 @ A1

IF IN DOUBT - ASK

NOTES

- Planning Boundary
- Proposed Inundation
- Proposed Dam
- Proposed Intake
- Proposed Surge Shaft
- Proposed Adit
- Proposed Shios Valve House and Fish Pool
- Proposed Leamhain Upper Gate House
- Proposed Leamhain Lower Valve House
- Proposed Tunnel
- Proposed Powerhouse
- Proposed Borrow Pit
- Proposed Compound
- Proposed Peninsula
- Proposed Aqueduct / Diversion Channel
- Proposed PSH Track
- Proposed Grid Route
- Proposed New Estate Track / Footpath
- Loch a' Bhealaich Leamhain Proposed to be Drawn Down to +610m During Construction

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P5	22.09.23	MH	Preliminary	GMcG	GMcG
P4	06.09.23	MH	Preliminary	GMcG	GMcG
P3	28.08.23	MH	Preliminary	GMcG	GMcG
P2	21.08.23	MH	Preliminary	GMcG	GMcG
P1	14.08.23	MH	Preliminary	GMcG	GMcG

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PROJECT
EARBA PSH

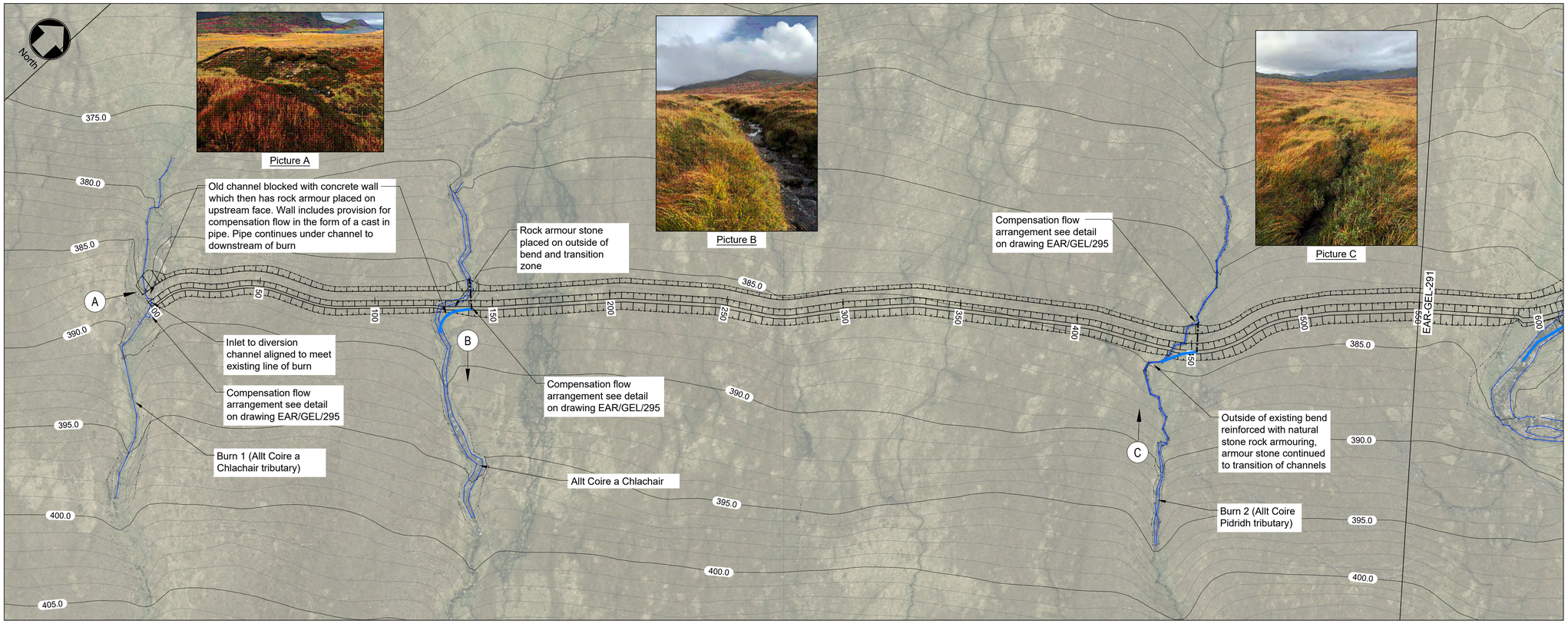
DRAWING TITLE
SCHEME ARRANGEMENT

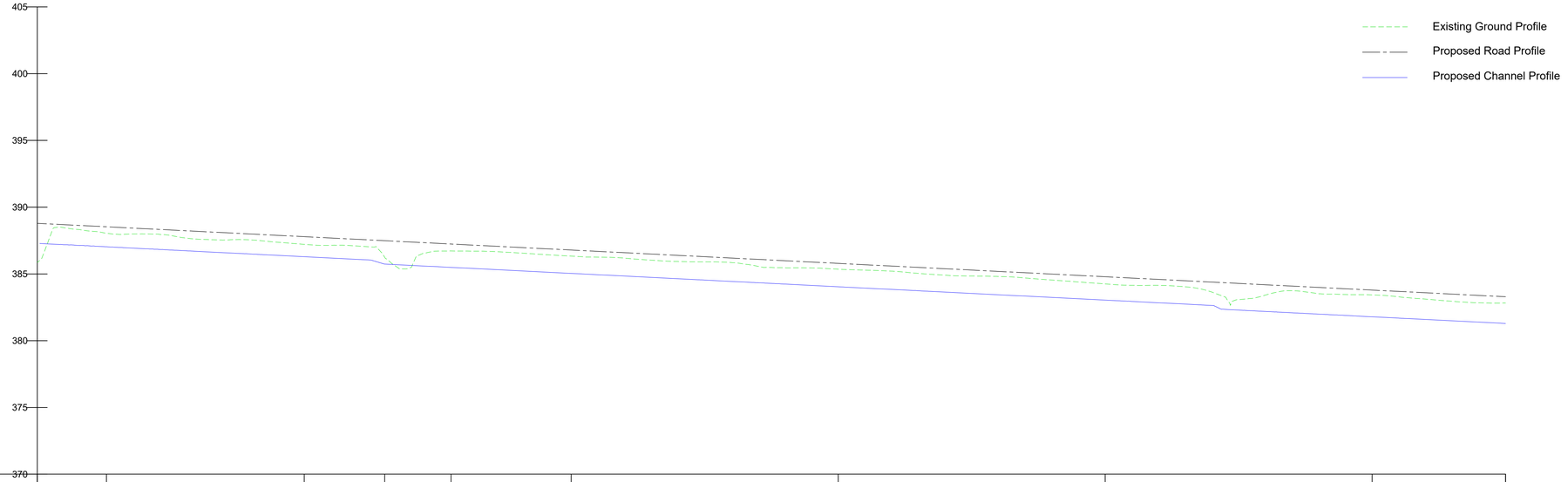
SCALE AT A1 (ORIGINAL SHEET SIZE)
1:20,000 — 0 — 1000m — 2000m

DRAWING NUMBER/REFERENCE
EAR/GEL/002

DRAWING STATUS
PRE

C PROPOSED DIVERSION CHANNEL DESIGN





LONGITUDINAL SECTION

(A-DIVERSION CHANNEL)

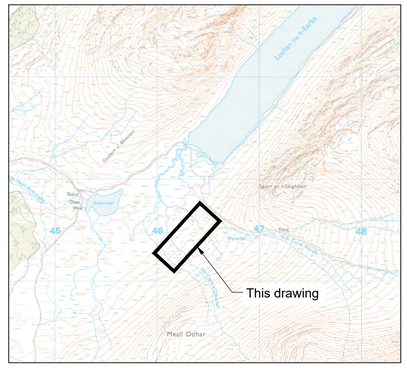
CHAINAGE: 0 TO 550
SCALE: H 1:1000, V 1:200

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		387.037	386.291	385.740	385.492	385.041	384.041	383.041	381.791	381.291

IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).
2. All dimensions are in metres unless otherwise noted.
3. Following detailed design local wider areas of the channel may be installed to allow a larger capacity in parts of the channel more susceptible to sediment build up.



Location Plan
1:30,000 @ A1

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P1	-	MW	Preliminary	DT	GRM

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DRAWING TITLE

SHUAS CHANNEL DIVERSION PLAN AND LONG SECTION SHEET 1

SCALE AT A1 (ORIGINAL SHEET SIZE)

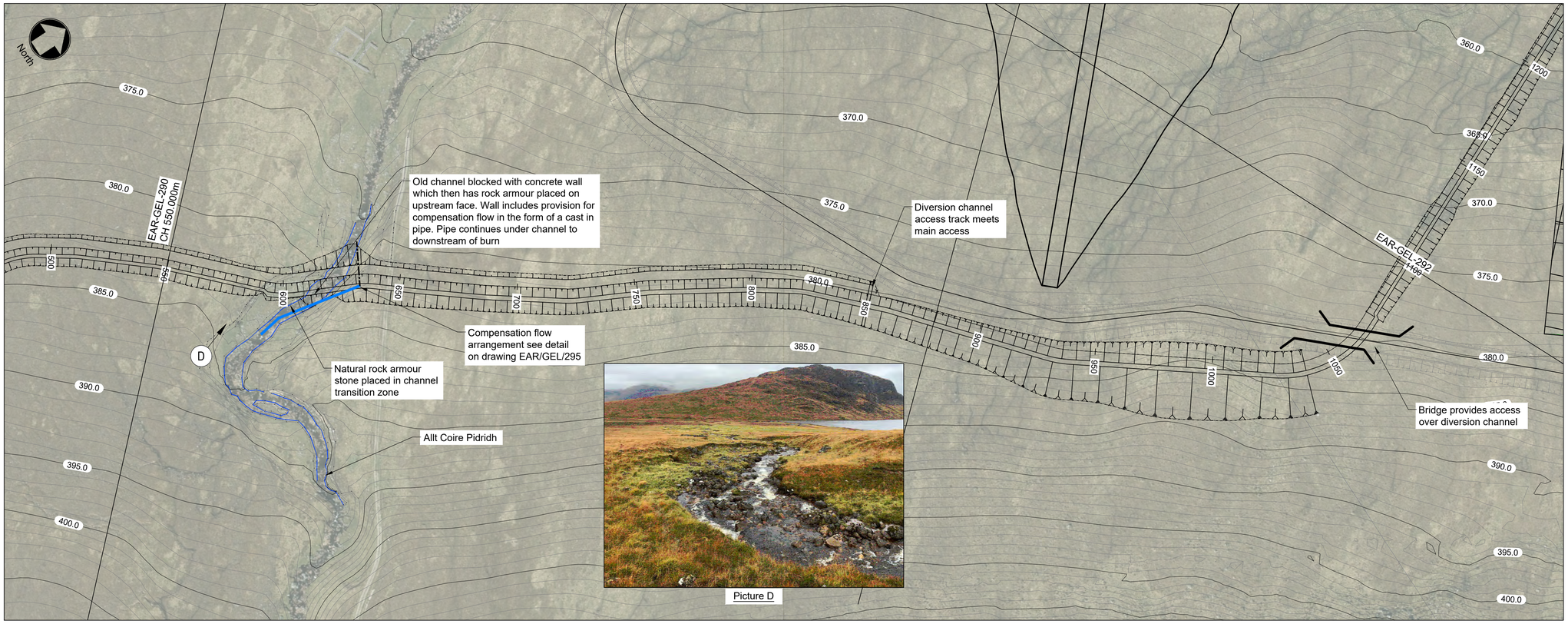
1:20,000 0 1000m 2000m

DRAWING NUMBER/REFERENCE

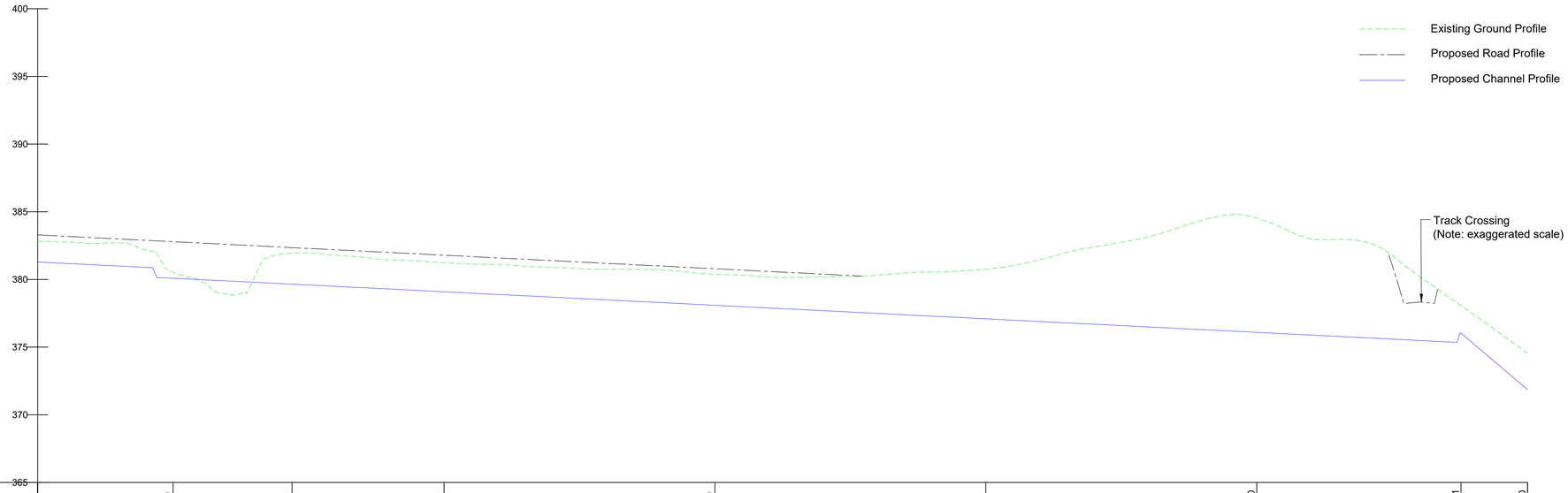
EAR/GEL/290

DRAWING STATUS

PRE



Picture D



LONGITUDINAL SECTION

(A-DIVERSION CHANNEL)

CHAINAGE: 550 TO 1100
SCALE: H 1:1000, V 1:200

Chainage	550.000	600.000	643.869	700.000	800.000	900.000	1000.000	1075.401	1100.000
Existing Levels	382.818	380.517	381.944	381.240	380.375	380.768	384.531	378.077	374.535
Proposed Levels	381.291	380.102	379.653	379.091	378.091	377.091	376.091	376.037	371.862

IF IN DOUBT - ASK

NOTES

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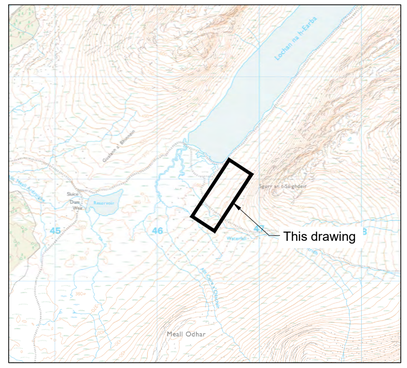
2. All dimensions are in metres unless otherwise noted.
3. Following detailed design local wider areas of the channel may be installed to allow a larger capacity in parts of the channel more susceptible to sediment build up.



Location Plan
1:30,000 @ A1

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P1	-	MW	Preliminary	DT	GRM

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DRAWING TITLE

SHUAS CHANNEL DIVERSION PLAN AND LONG SECTION SHEET 2

SCALE AT A1 (ORIGINAL SHEET SIZE)

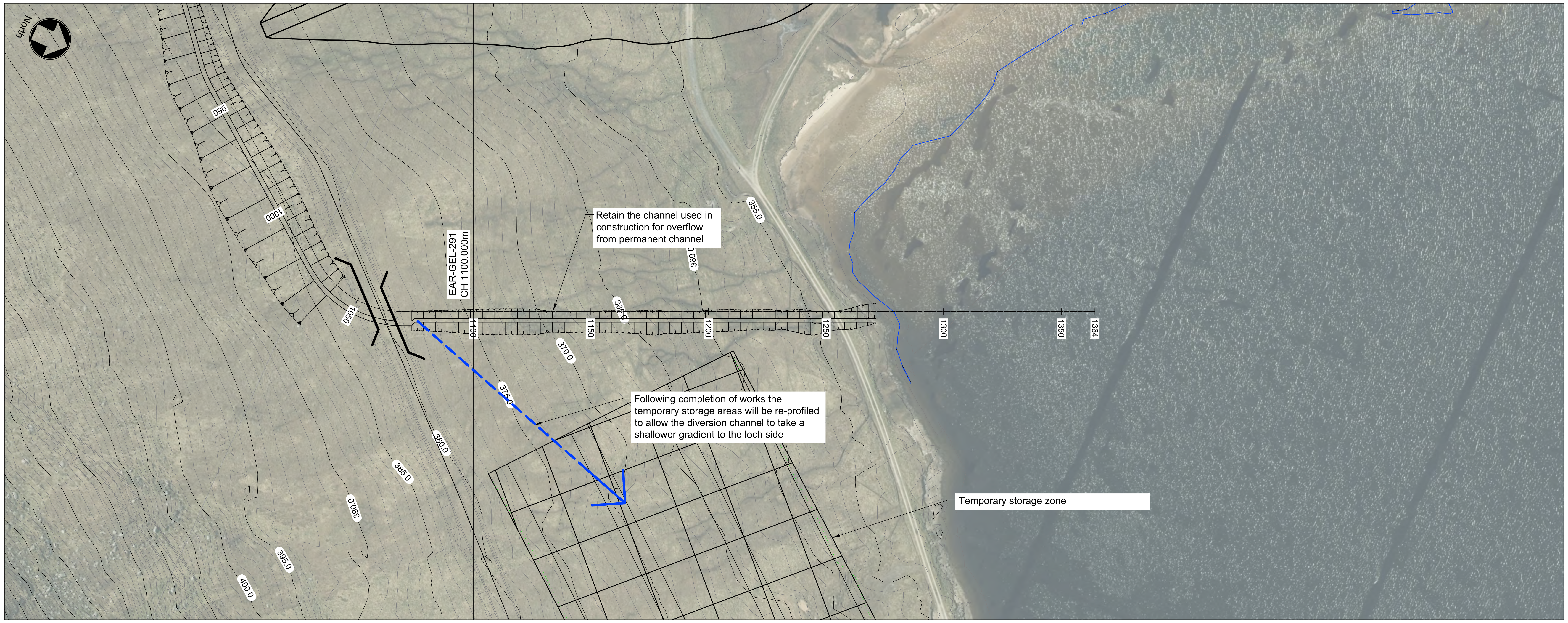
1:20,000 0 1000m 2000m

DRAWING NUMBER/REFERENCE

EAR/GEL/291

DRAWING STATUS

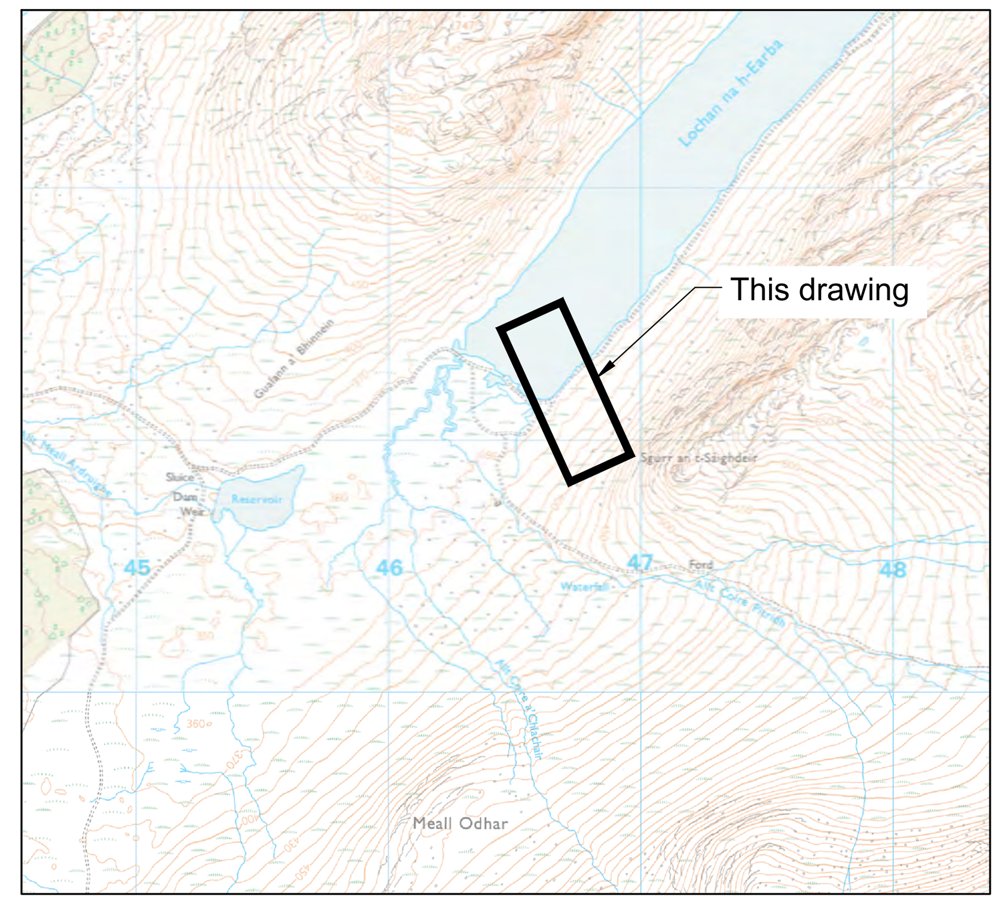
PRE



IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).
2. All dimensions are in metres unless otherwise noted.
3. Following detailed design local wider areas of the channel may be installed to allow a larger capacity in parts of the channel more susceptible to sediment build up.



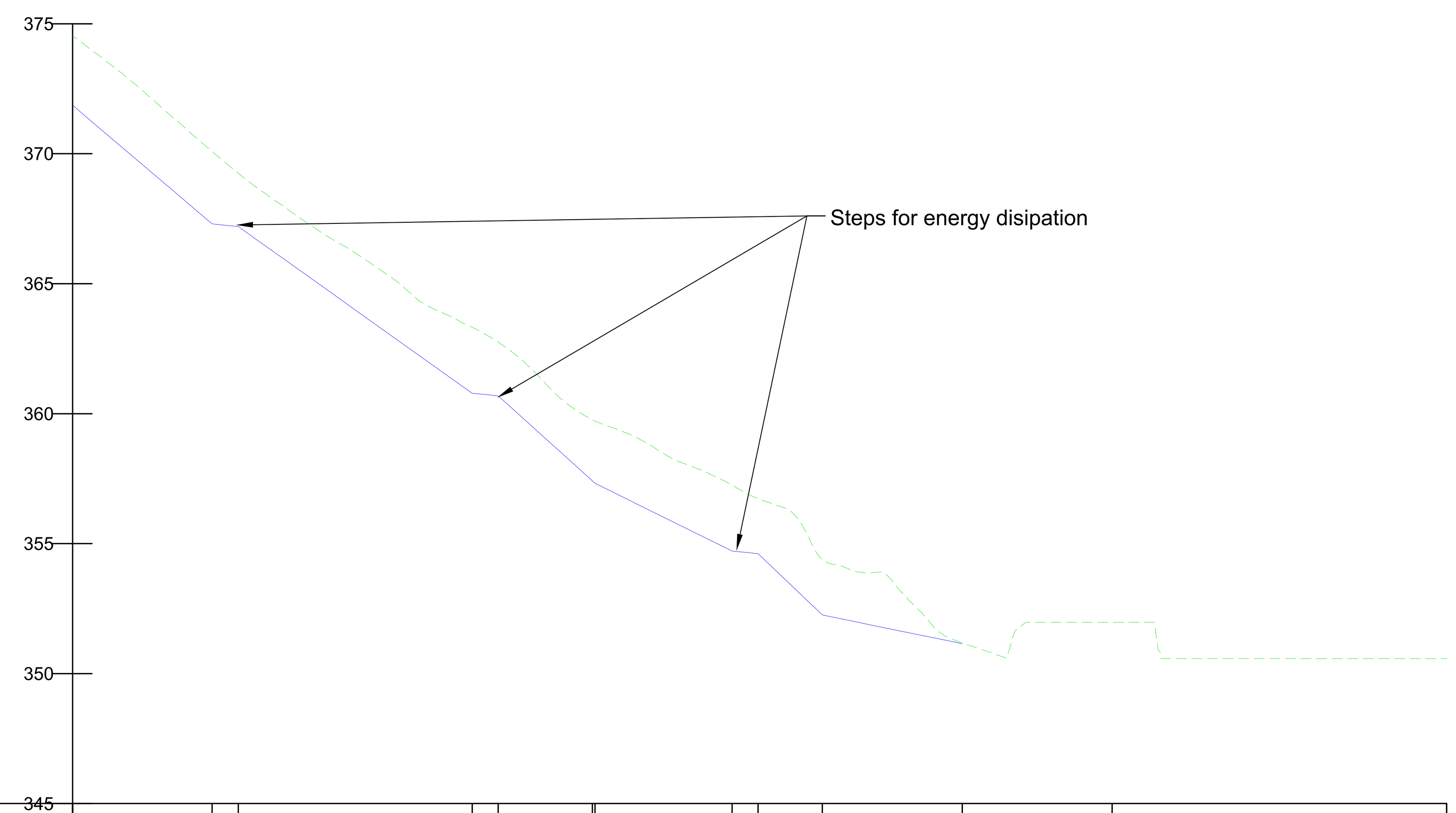
Location Plan
1:30,000 @ A1

Existing Ground Profile
Proposed Road Profile
Proposed Channel Profile

LONGITUDINAL SECTION

(A-DIVERSION CHANNEL)

CHAINAGE: 1100 TO 1364
SCALE: H 1:1000, V 1:200



Chainage	1100.000	1126.871	1131.871	1176.873	1181.873	1200.000	1200.524	1226.872	1231.872	1244.228	1271.162	1300.000	1364.318
Existing Levels	374.535	370.088	369.255	363.325	362.752	359.764	359.716	357.250	356.732	354.385	351.176	351.970	350.570
Proposed Levels	371.862	367.300	367.200	360.784	360.684	357.414	357.320	354.714	354.616	352.255	351.150		

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P1	-	MW	Preliminary	DT	GRM

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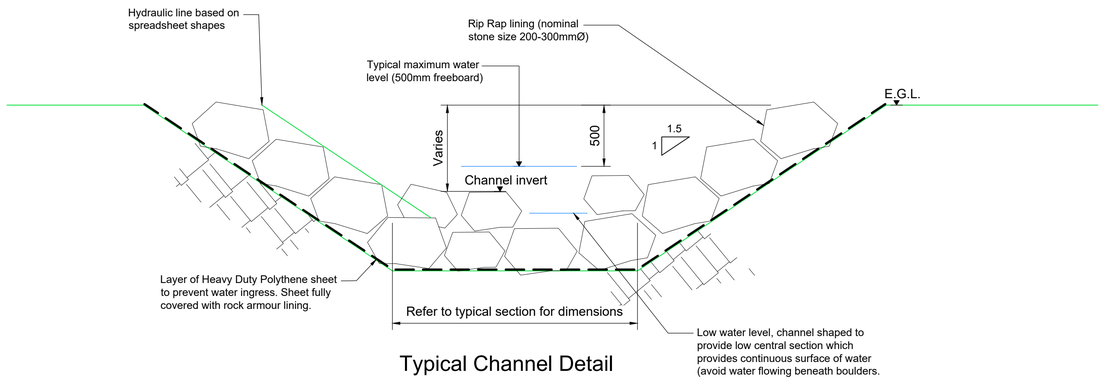
DRAWING TITLE
SHUAS CHANNEL DIVERSION PLAN AND LONG SECTION SHEET 3

SCALE AT A1 (ORIGINAL SHEET SIZE)
1:20,000 0 1000m 2000m

DRAWING NUMBER/REFERENCE
EAR/GEL/292

DRAWING STATUS
PRE



Typical Channel Detail

scale 1:25

Typical Channel Illustration

Note: As channel gets steeper the water flow is between rocks and the continuous surface is lost, the proposed channnel will be shaped to minimise this where possible.

IF IN DOUBT - ASK

NOTES

1. All levels are in metres above ordnance datum (mAOD).
2. All dimensions are in millimeters unless otherwise noted.

REV	DATE	DRAWN	NOTES	CH'K'D	APP'D
P1	-	MW	Preliminary	-	-

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DRAWING TITLE

TYPICAL DIVERSION CHANNEL DETAIL

SCALE AT A1 (ORIGINAL SHEET SIZE)

1:25 0 1250mm 2.5m

DRAWING NUMBER/REFERENCE

EAR/GEL/295

DRAWING STATUS

PRE