Kyleakin fish factory

Marine Harvest

Hydrogeomorphology Report

B2264800-GEOMORPH-001 | P01

01 March 2017

Client Reference

Document history and status

Revision	Date	Description	By	Review	Approved
V2	09/02/2017	Preliminary Geomorphology Assessment	Lucy Shuker	Andrew Brookes	Alan Brown
V3	02/03/2017	Hydrogeomorphology Report	Lucy Shuker	Andrew Brookes	Alan Brown

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments

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Project No:	Project Number
Document Title:	Hydrogeomorphology Report
Document No.:	B2264800-GEOMORPH-001
Revision:	P01
Date:	01 March 2017
Client Name:	Marine Harvest
Client No:	Client Reference
Project Manager:	Alan Brown
Author:	Lucy Shuker
File Name:	\\europe.jacobs.com\reading\Admin\Geomorphology\B2261401 Skye Kyleakin\Geomorph Report\HydroGeomorph Report_ Kyleakin Alt Anavig 02Mar17.docx

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Contents

1. Introduction

1.1 Background

The purpose of this report is to provide a hydro-geomorphological assessment and recommendations in relation to proposed works at Kyleakin Quarry, Skye in line with the Environmental Standards for River Morphology (SEPA, 2012). This guidance is provided by SEPA to determine the potential impacts of proposed activities upon the aquatic environment in Scotland to meet the requirements of the EU Water Framework Directive (WFD), enacted through the Water Environment Water Services (WEWS) Act 2003 and The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).

Hydro-geomorphology describes the physical characteristics and fluvial processes present and functioning within a river system. This report presents an overview of the dominant hydro-geomorphological processes and characteristics of the Alt Anavig watercourse, which would be modified as a consequence of the proposed development. Planning conditions and supporting information from SEPA reproduced in Box 1 include the requirement for a 'Hydrogeomorphologcial Assessment to show improvements in the design of the new watercourse', 'to minimise the use of culverts and hard engineering where possible….. something with morphological processes'

The content is informed by desk study and a geomorphological reconnaissance assessment undertaken at the Kyleakin Quarry on the Isle of Skye, on 6th January 2017.

Box 1

DRAFT Planning Condition no. 5

No development shall commence until an updated Flood Risk Assessment (FRA), a Hydro-geomorphological Assessment of the proposed watercourse and an updated site plan have been submitted to and approved in writing by the planning authority. The submitted details should show the following;

- *that the finished floor levels of the buildings are set no lower than 8.25m AOD*
- *the finished site levels*
- *the watercourse design and alignment including offtake weirs*
- *the results of a comprehensive structural survey of the existing culvert and details of any repair work required*
- *the FRA to demonstrate that in the event of a culvert blockage flood waters can be directed safely around the buildings without internal flooding*
- *the FRA to include inspection schedules and mitigation measures to prevent blockages of the existing and proposed culverts*
- *the FRA to inform and include a safe dry access/egress route from the buildings in the event of flooding*
- *the FRA to include a final surface water drainage design that demonstrates capacity to manage a 1 in 200 year return period event with adequate treatment systems incorporated*
- *the Hydrogeomorphological Assessment to show improvements in the design of the new watercourse as outlined at paragraph 9.1 and 9.2 of SEPA's consultation response to the planning authority dated 19 January 2017*

The development shall not proceed other than in accordance with the approved details.

Reason *: In the interests of minimising flood risk*

Paragraphs 9.1 and 9.2 of SEPA's consultation response to the planning authority (19 January 2017)

9**. Hydrogeomorphology**

9.1 The diverted watercourse will flow through a closed pipe (62.1095 m), a culvert (18.4 m) and two sections of open channels (95.53 m combined). The open channels will have an unnatural uniform planform and concrete lined boundaries. Furthermore, the diverted channel will be of high energy, with a number of abrupt changes in gradient. As such our main concerns with the design are:

a) There will be no coarse sediment supply through the diverted reach due to culverts and the reservoir upstream likely acting as sediment traps. Consequently, this high energy stream will have the potential for significant erosion. As it stands this could be at the outfall into the existing lagoon and downstream from the end of the design during lower tides, unless mitigation measures are put in place. Without mitigation this will place a significant maintenance burden upon the operator of the site.

b) With the artificial design there is unlikely to be any morphological function within the channel and so there is no improvement to the existing watercourse.

9.2 Through the condition requested in Section 1 above, we would seek to see improvements in the design to minimise the use of culverts and hard engineering where possible. Whilst the constraints imposed on its location are unlikely to allow reinstatement of a natural channel that mimics its unmodified form, we would encourage something with morphological processes. A robust design would require significant input from an appropriately qualified fluvial geomorphologist.

2. Geomorphological investigation

2.1 Desk Study

2.1.1 Background

The Kyleakin site on the eastern side of the Isle of Skye has been disused since the historic extraction of palaeoglacial deposits shaped the current form of the site into a quarry (now disused). The site is located adjacent to the coast of the Inner Sound to the west of Kyle Akin. Proposals by the developer Marine Harvest for the site include construction of a fish feed factory, encompassing processing facilities, waste treatment and new jetty and slipway.

For most of its length, upstream of the A87, the Alt Anavig is a relatively unmodified high energy stream with several small natural tributaries, draining a catchment of over 5km^2. Upstream land use is mainly rough pasture with some managed commercial woodland.

Using the SEPA online River Basin Management Plan (RBMP) Interactive map (http://gis.sepa.org.uk/rbmp/), the Alt Anavig is recorded (by its upstream name, Allt Lochan na Saile) as a 'Small River Water Body'. Due to its small catchment size, the Allt Lochan na Saile is not classified within the Scotland RBMP. However adjacent classified waterbodies (such as the Abhainn Lusa) are reported as having High ecological status, with an overall objective for no deterioration under EU WFD and WEWs Act requirements, unless activities provide significant specified benefits to society or the wider environment (SEPA, 2010).

SEPA's 2012 Supporting Guidance (WAT-SG-21) indicates that watercourses identified as 'Small River Water Bodies' should undertake Step 2 of the Environmental Standards Test, involving the application of MImAS '*to the 500m section of channel surrounding the proposed activity to see whether or not the activity is sufficiently significant to downgrade this local section of channel'.*

2.1.2 Local geology, superficial deposits and ground conditions

The current river channel, riparian corridor, adjacent landscape (including the quarry and beach) are dominated by the palaeoglacial marine deposits laid down between 2 and 3 million years ago respectively, with some organic material originating from peat bogs (British Geological Society, http://mapapps.bgs.ac.uk/). Originally formed on marine shorelines and in shallow seas, these deposits are now elevated above current sea levels. These raised shoreline features were formed at the time of the retreat of Scotland's last ice sheet approximately 15,000 years ago. More recently they have been quarried by sand and gravel extraction industries (Stephenson and Merritt, 2006; Howe et al, 2012).

Ground investigations confirm the terrain to be dominated by unconsolidated sediments with areas of peat underlying the current quarry level ground surface (Fairhurst, 2016). The proximity of underlying peat to proposed work should be considered in detailed design, in particular along the course of the new culverted channel, the area between the toe of the reservoir retaining embankment and the lower level lagoon.

2.2 Field observations: Alt Anavig and Kyle Akin foreshore

A baseline hydro-geomorphological reconnaissance survey of the Alt Anavig was carried out during a site visit to the Kyleakin Quarry on 6th January 2017. Weather conditions were good with only slight rain and wind, therefore good channel visibility and normal flow conditions. The survey consisted of a walkover to visually appraise and record the key geomorphological characteristics present including: river type, bed and bank materials, channel morphology and notable features, aquatic and riparian vegetation; also modifications to the fluvial and riparian environments. A walkover of the Kyle Akin foreshore and embankments in the location of the proposed and existing outfalls was undertaken at the same time. Further observations of adjacent water courses (carried out where access allowed clear views) including upstream sections of the Alt Anavig and Abhainn Lusa, confirmed the similarity of the character and dimensions of more natural open channels to that of the Alt Anavig within the site (i.e. 4-5m bed width) to be incorporated into the design to prevent sedimentation issues.

The Alt Anavig flows through the Kyleakin Quarry site for approximately 500m, entering the site from the north as a semi natural open channel emerging from a culvert beneath the A87 (at NGR: NG73266608), to the southern boundary where it discharges to the sea from a second culvert outfall (at NGR: NG 7326 8748). Immediately upstream and downstream of the A87 culvert, the Alt Anavig appears to have a relatively natural morphology, functioning as a plane bed channel within a narrow wooded valley, with occasional bank reinforcement consisting of stone revetments. Around 100m downstream of the A87, the Alt Anavig has a small on-line reservoir of approximately 0.5ha surface area, formed as an embanked impoundment (at NGR: NG73267723). Photographs of the existing channel and reservoir are provided in Appendix A1 - Alt Anavig images.

Within the Kyleakin Quarry site, the existing Alt Anavig channel has been modified along most of its course with two lengths of semi-natural channel, each approximately 100m in length by 4-5m width. Historic maps dating back to 1876 indicate these channel lengths align with the original historic flow path (www.old-maps.co.uk) (i.e. pre quarrying activities). The two lengths are currently separated by the on-line reservoir which is impounded within an historic meander bend. Based upon SEPA guidance (SEPA, 2012), the reference typology of the Alt Anavig within the quarry is predominantly Type B plane bed, with a short semi-natural length of Type A cascade immediately downstream of the reservoir outfall.

The channel bed is currently dominated by cobble-boulder substrate with bank reinforcement in some lengths, mainly consisting of rock revetment, combined with concrete where other infrastructure is present e.g. culverts or pipe crossings. The riparian corridor of the open channels consists of steep sided narrow valleys with scrub vegetation and small trees (see Appendix A1 – Alt Anavig images).

Finer gravel substrate was visible but limited to a few depositional locations where the channel morphology limited transport, i.e. upstream of impounding structures (at the upper culvert and reservoir outlets) and at one point bar. The absence of gravel fraction within the main channel substrate suggests a transport dominated system whereby most of the finer materials have been mobilised and scoured out through current hydro-geomorphological processes.

Downstream of the reservoir, the Alt Anavig enters an extended culvert (at NGR: NG 73267632) of approximately185m, consisting of a circular corrugated pipeline approximately 2m diameter, before discharging to the marine environment immediately east of the current pier structure. The current capacity of the downstream culverted section is below the volume of the 1 in 25 year or 0.04 / 4% probability rainfall event. There is therefore a need to increase the discharge capacity of the Anavig at the site to avoid flooding the proposed built development (i.e. the Marine Harvest Fish Feed Factory).

Observations confirm the high flow energy environment of the open channel through evidence of the existing channel dimensions (bed width 4-5m) and large bed substrate (cobble / boulder). The limited presence of gravels within the bed materials indicates their poor supply and replenishment due to the upstream channel modifications and influence of the impounded reservoir, which is currently acting as a sediment trap. The potential for erosion and scour, exacerbated by the locally depleted sediment supply and transport, could potentially influence the long term stability of a re-engineered channel downstream of the reservoir.

3. Proposed works

Proposed works include a major diversion of the course of the lower Alt Anavig, discharging from the reservoir via an alternative outlet to a new artificial closed and open culverted channel and passing through a man-made lagoon, before discharging to the sea via a more semi-natural engineered open channel.

Proposals for on-site surface water management include retention of the existing semi-natural open river channel and closed culvert for flood relief purposes only. The new diversion channels would be designed to accommodate flows up to approximately the 2% AEP (or 1 in 50 year return period) event equivalent to at least 22.2m^3/s. The remaining part of the flow (in all conditions up to and including the 200 year plus climate change event) would be approximately13.9m^3/s and spill over the existing spillway and flow down the current semi-natural channel and culvert to discharge via a new outfall to be developed at the slipway east of the existing pier.

3.1 Channel upstream: reservoir outfall to lagoon

At the reservoir outfall, a concrete spillway would divert flow at a 90^o angle into an artificial closed culvert down a slope of approximately 1:17. At the current ground level the channel would change to an open culvert with a reduced gradient.

The new diversion channel would discharge to an existing man-made lagoon. At each transition between channel lengths there would be a risk of erosion due to the high velocities and turbulence generated at these critical points. To reduce the risk of erosion at the junction of culverted reaches, energy dissipation would be required, either in the form of an engineered stilling basin combined with additional roughness and/or by additional capacity within the box culvert. At the lagoon, energy would dissipate as a consequence of the increased capacity of the proposed channel. However management of localised bed and/or erosion risks should involve further investigation of existing bed substrate and underlying ground conditions / local superficial sediments with the inclusion of suitable, stable coarse bed materials such as locally sourced rock revetment.

Potentially adverse hydro-geomorphological impacts arising from the current proposed option for channel upstream and recommendations for additional mitigation (where applicable) include:

- 100% depletion of the existing (90m) stretch of semi-natural channel (up to 0.5% probability flood event),

- The first length of concrete spillway would require sheet piling into the existing reservoir bund. Care would be needed to avoid potentially destabilising the structural integrity of the retaining embankment and associated landforms.

- Scale of earthworks, slope stabilisation would be required to fit pipe and open culverts with capacity for up to 22.2 m^3/s (estimated for 0.5% probability event), estimated as 2.5m diameter.

- An engineered solution has been proposed to address the potential risks of erosion and corresponding deposition of scoured bed and/or bank materials, including increased bed roughness to reduce hydraulic energy. In particular, this would be a priority activity at changes of slope where velocities and turbulence would be greatest. These include sharp changes in slope between the closed culvert and open channel lengths, at the lagoon and also at location of discharge to beach foreshore.

- Sediment release during works, including: site clearance operations and the construction of culverts and new open channels would be managed through the contractor’s construction methodology and Construction Environment Management Plan (CEMP) to avoid slope or bank failure and associated risks, including the mobilisation of fine sediments which could potentially lead to smothering of fluvial or marine sediments downstream.

3.2 Channel downstream: lagoon outfall to foreshore

Immediately downstream of the artificial lagoon, an outfall would convey flows through a trapezoidal open channel to a new marine discharge location on the beach. The new channel would include a section of box culvert underneath the existing access road, as well as a deep cutting through the existing high embankment, currently located between the main quarry and the foreshore.

At the outfall from the lagoon, a step pool cascade would dissipate energy before the culverted access road crossing. Two options for the size of the box culvert currently exist (Option 1: 3.6 x 2.4m; Option 2: 6.0 x 3.6) in combination with different scour pool requirements (Option 1: 28m long x 20.1m wide; Option 2: 25.4m long x 18.1m wide). Option 1 would include a larger downstream naturalised scour pool (resulting from increased energy) in combination with a shorter sequence of step pools, constructed using local boulders with a cobble-gravel-mix for bed materials. With respect to conveyance and erosion management at the culvert, the larger aperture of Option 2 would reduce downstream scour; in combination with a shallow V-cut channel bed combined with coarse substrate it would support hydrogeomorphological processes, habitat functionality and continuity between the upstream and downstream reaches. For both options, the construction of a shallow V-cut bed profile would allow a low flow channel to maintain transport of fine sediment materials across a range of flow stages.

The open channel section from the access road culvert to the foreshore would have a relatively shallow gradient compared to the upstream channel, but enough slope to sustain a step pool series, providing valuable intertidal habitat with potential to act as a refuge for marine species. The introduction of coarse to large sediment and inclusion of a low flow channel would help to prevent smothering of the bed with fine sediments and provide habitat diversity to support the Kyle Akin Marine Protected Area immediately adjacent to the site.

Scour protection at the foreshore discharge point would include locally sourced rock armour to dissipate energy.

Post-construction, management of sediment inputs to the channel in the downstream length would be managed through the use of biodegradable seeded geo-textile on new bank/embankment faces to support the establishment of vegetation cover for longer-term slope stabilisation.

3.3 Recommendations

3.3.1 Embedded (or primary) mitigations

- Wash-out valves or scour valves should be located through the intake structures at the lowest point of the river channel bed and occasionally opened to flush out sediment collected upstream of the structure, allowing it to be distributed downstream over time.

- The spillway should be profiled at the intakes to protect the banks and downstream channel.

- Intake walls should include wing walls designed to provide protection from erosion to banks immediately upstream.

- During flood events, water would flow down the current channel (to be flow depleted as part of proposed works). Water overtopping the intake structures would transport smaller (gravel) sediments downstream during high energy flow events.

- Baffles should be incorporated into the design of outfalls, spillways and culvert structures to reduce the energy of the discharge flow.

- Scour protection would be required at all outfalls and discharge locations (especially onto the beach foreshore).

- Lengthening the path of the proposed route would offer reduced flow energy within the proposed culvert design.

- The 'design life' costs of an artificial realignment option should also take into consideration the expense of ongoing management and maintenance activities. In particular, regular inspections to identify blockages within closed culvert sections and their safe removal should be factored in to reduce the risks of flooding to infrastructure and ensure work force safety.

- As part of the proposed option, the open artificial channel should be naturalised as far as is practicable i.e. designed to work with the underlying geology and utilise locally sourced natural bed materials that could withstand modelled hydraulic parameters, e.g. extra-large (car size) blocks of stone.

- Bed permeability – channel would need to be clay-lined below rough sediment layer to prevent flow loss, a clay-gravel-cobble mix using local materials where possible is recommended.

- Channel boundary stability – bed control structures, such as headwalls, would need to be keyed into stable ground (bedrock or concrete foundations).

- Channel substrate stability – where naturalised measures are possible to dissipate flow energy, a mixed boulder-cobble substrate would be installed as detailed within the Reservoir Outlet Hydraulics Report B2264800-GEOMORPH-001 (Jacobs, 2017)

- Within the tidal length downstream of the box culvert, the inclusion of a V-cut bed to accommodate and maximise the transport efficiency of multi-stage flows, would also improve connectivity to the sea (marine environment), potentially providing habitat for suitable for marine / estuarine species seeking refugia.

- Channel substrate diversity comprising of a mixed boulder/cobble bed, would provide locally variable flows and physical conditions with potential for juvenile nursery inter-tidal habitat for marine species in the adjacent Kyle Akin Marine Protected Area, thereby offsetting the loss of the historic estuarine reach of the Alt Anavig prior to construction of the existing culvert.

3.3.2 Standard (or tertiary) mitigation - Environmental Regulations / Good Practice

Details of design and construction methods and a CEMP (if appropriate) would be agreed with SEPA, in line with requirements under relevant good practice guidance, including:

- SEPA's Position Statement to support the implementation of the Water Environment (Controlled Activities) (Scotland) Regulations 2005: WAT-PS-06-02: Culverting of Watercourses (SEPA, 2015);
- SEPA's Engineering in the Water Environment Good Practice Guide: Bank Protection Rivers and Lochs (WAT-SG-23) (SEPA, 2008b)
- SEPA's Engineering in the Water Environment Good Practice Guide: Intakes and Outfalls (WAT-SG-28) (SEPA, 2008c)
- SEPA's Position Statement to support the implantation of the Water Environment (Controlled Activities) (Scotland) Regulations 2011: WAT-PS-07-02: Bank Protection (SEPA, 2012a)
- SEPA's Supporting Guidance (WAT-SG-21) Environmental Standards for River Morphology (SEPA, 2012b).

In line with SEPA's guidance on river morphology (SEPA, 2012b), the application of the Environmental Standards Test provides an opportunity to meet current regulatory requirements by asking three questions as follows:

- Is there a demonstrated need for the activity?
- If so, has a range of options been considered and the option which minimises environmental harm without disproportionate cost selected?

- Has all reasonable mitigation been identified and implemented?

3.3.3 Specific (or secondary) mitigation

As well as maintenance inspections to check for possible blockages within the closed culvert, scour and sedimentation would need to be monitored, in particular around the junctions of the engineered channel lengths, at restricted apertures and the naturalised open channel to enable all lengths to function in line with design specifications.

The detailed design of the watercourse diversion, and particularly at changes in bed slope, would need to accommodate flow rates and velocities identified by the hydraulic model. Suitable materials (as recommended above and within the Reservoir Outlet Hydraulic report) and construction methods would need to be adopted to ensure the long-term sustainability of the channel as a whole, including all maintenance requirements within the proposed culvert.

4. Conclusions

The proposed development at the Kyleakin quarry requires the diversion of the Alt Anavig to increase conveyance capacity at the site to accommodate the 0.5% AEP (1 in 200 year) event plus climate change within a new channel (to convey up to the 0.2% AEP (1 in 50 year) event) and in combination with the existing watercourse (for the higher 0.5% AEP or 1 in 200 year event plus climate change).

A range of options for the channel upstream and downstream of the existing lagoon (which will form part of the new planform) has been considered, leading to the proposal for an engineered solution for the upstream channel reach, combined with a semi-naturalised open channel from the lagoon to marine outfall.

Proposed mitigation measures to control the potential risks of erosion and to offset deterioration of the existing open channel would be embedded within the designs of the two reaches and applied through adherence to best practice in line with SEPA guidance (SEPA 2008b, 2008c, 2012a, 2012b. 20115).

Although site constraints limit the opportunity for hydrogeomorphological processes within the upstream channel, through the proposed works, the lower estuarine reach of the Alt Anavig would be reinstated as an alternative mitigation. The creation of a new semi-natural open channel between the lagoon and marine outfall would provide a new estuarine reach for the Alt Anavig, previously lost through the construction of the existing culvert, recreating juvenile and nursery inter-tidal habitat for marine species within the Kyle Akin Marine Protected Area.

5. References

British Geological Society – Bedrock and Superficial deposits, Land and Offshore datasets http://mapapps.bgs.ac.uk/geologyofbritain/home.html (Accessed 11th November 2016)

Fairhurst (2016) Proposed Salmond Feed Plant, Kyleakin, Isle of Skye: Geo-environmental and Geotechnical Interpretative Report.

Historic Map Views. OS County Series ISLE OF SKYE 1876 – 1878 1:2500 https://www.old-maps.co.uk/#/Map/173785/826250/12/100297 Accessed 17th February 2017

Howe, John A.; Dove, Dayton; Bradwell, Tom; Gafeira, Joana. (2012) *Submarine geomorphology and glacial history of the Sea of the Hebrides*, *UK. Marine Geology,* 315-318. 64-76. 10.1016/j.margeo.2012.06.005 http://nora.nerc.ac.uk/500620/ (Accessed 11th November 2016)

SEPA (2010) RBMP Water body information sheet for water body 20710 in West Highland. http://apps.sepa.org.uk/rbmp/pdf/20710.pdf . Accessed 17th February 2017

SEPA (2012) Supporting Guidance (WAT-SG-21) Environmental Standards for River Morphology v 2.1 July 2012

SEPA (2008a) Classification information reported to Europe in the Scotland RBMP (2008-2015) viewed via the SEPA RBMP Interactive Map. http://gis.sepa.org.uk/rbmp/ Accessed 17th February 2017

SEPA (2008b) Engineering in the Water Environment Good Practice Guide: Bank Protection Rivers and Lochs (WAT-SG-23)

SEPA (2008c) Engineering in the Water Environment Good Practice Guide: Intakes and Outfalls (WAT-SG-28)

SEPA (2012a) Position Statement to support the implantation of the Water Environment (Controlled Activities) (Scotland) Regulations 2011: WAT-PS-07-02: Bank Protection

SEPA (2012b) Supporting Guidance (WAT-SG-21) Environmental Standards for River Morphology

SEPA (2015) Position Statement to support the implementation of the Water Environment (Controlled Activities) (Scotland) Regulations 2005: WAT-PS-06-02: Culverting of Watercourses

Stephenson and Merritt (2006) *Skye – A landscape fashioned by geology* SNH http://www.snh.org.uk/pdfs/publications/geology/skye.pdf

Appendix A. Alt Anavig images

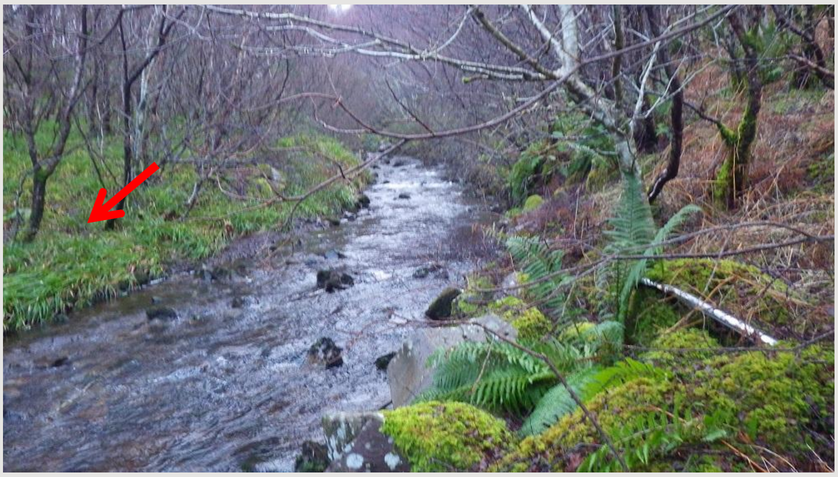
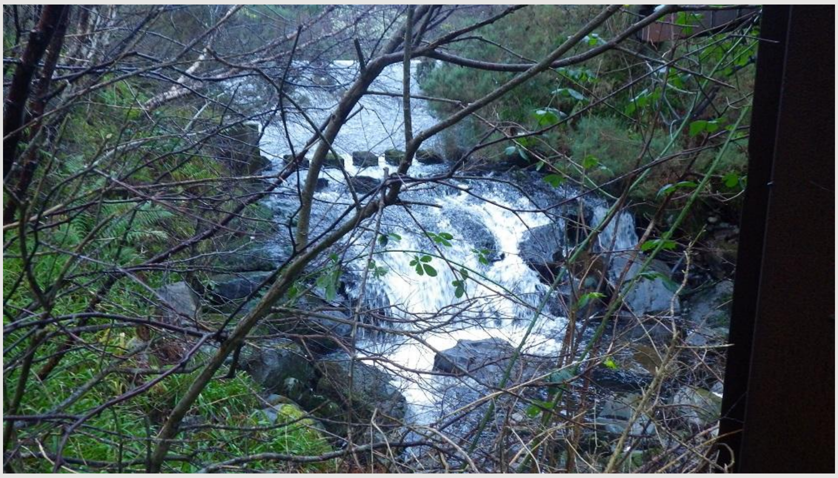
	Figure A1.1 Alt Anavig upstream of A87, showing semi-natural channel form within steep valley; also trash line and high flow level along treeline on right bank (left side of image), approximately 0.7m above shown water level
	Figure A1.2 Alt Anavig downstream of A87, showing large boulders exposed within plane channel and additional revetment at pipe crossing point on face of left bank.
	Figure A1.3 Reservoir impoundment on Alt Anavig

	Figure A1.4 Alt Anavig –spillway at the reservoir outlet, showing accumulations of finer sediments (gravel and silt) retained behind concrete crest, concrete wing walls and boulder revetments approximately 1.8-2.0m above water level.
	Figure A1.5 Alt Anavig – view upstream of current discharge from reservoir, showing concrete spillway apron with baffles and boulder waterfall dissipating hydraulic energy at steepest channel length
	Figure A1.6 Alt Anavig – view downstream showing boulder with cobble / coarse gravel riffle bed dissipating residual energy along lower gradient slope