GAVIA
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CRUACHAN 1 PUMPED HYDROSCHEME UPGRADE

CRUACHAN 1: FISH MITIGATION MEASURE REVIEW

STANTEC

18/01/2023

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Project number P23009

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Revision History

Revision	Date	Prepared By	Reviewed By	Approved By	Comments
1.0	19/12/2022	AG	DM	MH	Draft for client comments / data provision
2.0		SAS			
2.1	17/01/2022	DM	MH	MH	Revision following client comments / meeting
2.2	18/01/2022	DM	MH	MH	Revision following client comments

Quality Assurance

This report has been prepared according to Gavia Environmental Quality Management Process. Gavia Environmental employs consultant scientists who are members of appropriate professional institutions and adhere to professional codes of conduct.

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Executive Summary

Gavia Environmental Ltd. ('GEL') was commissioned by Stantec ('the Client') to undertake a review of current fish mitigation measures and recommend further mitigation measures that could be taken to reduce potential impacts on fish when upgrades are made to Units 3 and 4 of the existing Cruachan Pumped Storage Scheme. ('the Development'). Cruachan 1 is located at Grid reference: NN080281, approximately 4 km west of Awe Barrage Power Station and 11 km east of Dalmally in Argyll and Bute.

Stantec is contracted by Drax which proposes to upgrade the existing Cruachan Pumped Storage Scheme. Pumped storage units were commissioned in 1965 and the existing Cruachan Reservoir can store 2.4 billion gallons of water. Plans for the Development are to replace Units 3 and 4 to increase the efficiency of the scheme and electrical capacity (megawatt) output.

Salmonid species such as Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta*), European eel (*Anguilla anguilla*) and Arctic charr (*Salvelinus alpinus*) have been identified within Loch Awe. Migratory species heavily rely on environmental cues such as discharge and temperature to initiate their migration strategy, swimming passively throughout their seaward migration. Additionally, adults return to their natal tributaries (actively swimming) to spawn. Disruption to migration behaviours is detrimental for the success of reproduction and continuation of the species population.

In this report various mitigation is proposed to minimise impacts by the proposed upgrade of Units 3 and 4 on fish. Mitigation includes:

1. Continue with the use of Fish Screening;
2. Continue to Implement Velocity Monitoring and Control;

If it is found that the cumulative intake velocity of running all four Units is greater than 0.3 m/s, additional mitigation would be required (See 3.):

3. Limiting Operation of Pumps During Sensitive Smolt Migration Periods.

1 Introduction

Gavia Environmental Ltd. ('GEL') was commissioned by Stantec ('the Client') to undertake a review of current fish mitigation measures and recommend further mitigation measures that could be taken to reduce potential impacts on fish when upgrades are made to Units 3 and 4 of the existing Cruachan Pumped Storage Scheme. ('the Development'). Cruachan 1 is located at Grid reference: NN080281, approximately 4 km west of Awe Barrage Power Station and 11 km east of Dalmally in Argyll and Bute.

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The likely impacts relate to the potential increase in velocity of both drawdown and augmentation of water through the inlet/outlet pipes as a result of new mechanical equipment and the potential impact it could have on fish populations within the existing Cruachan reservoir and Loch Awe.

2 Project Personnel

Table 1 below lists the project personnel.

Table 1. Project Personnel

Personnel	Role
Amy Green	Environmental Consultant
Donald Morrison	Principal Consultant & Team Lead for Aquatic Ecology

3 Methodology

3.1 Study Objectives

The objectives of this report were to:

- Establish and review current fish mitigation practices in place; and
- Provide potential future fish mitigation options during operation of the upgraded units.

3.2 Desk Study

A desktop study was carried out at the start of the commission. Information sources used for this study are described below:

- **Scotland's Environment Web (2022)** – to obtain data on obstacles to fish migration on affected watercourses and to determine expected species within the surrounding location (~2 km area boundary);
- **NBN Atlas Scotland (2022)** – to perform a search to identify nature conservation interests.

3.2.1 Nature Conservation Features

3.2.1.1 Salmonids

Desk study research has identified the potential for Atlantic salmon (*Salmo salar*) and brown / sea trout (*Salmo trutta*) to reside within Loch Awe[1]. Additionally, research has identified the potential for Arctic charr (*Salvelinus alpinus*) within Loch Awe and because of water being pumped from Loch Awe, there is also historic data which suggested an Arctic charr population located in the Cruachan Reservoir, some 300 m above[2]. Field studies conducted for the Cruachan 2 EIA (ECU00004492) found no optimal habitat for Charr spawning within the reservoir. Constant fluctuations in the level of the reservoir is also a limiting factor for salmonid egg viability. Arctic charr are found within 5 km of the Cruachan Reservoir as highlighted by NBN Atlas Scotland[3]. Four records have been documented and verified. However, these are within Loch Awe and not Cruachan Reservoir itself. Each record has a CC-BY license and is available for commercial use.

Atlantic salmon, sea trout and Arctic charr, are of ecological value whereby Atlantic salmon have been listed in annexes II and V of the European Union's Habitats Directive as a species of European importance[4]. Migration is a common life cycle strategy for salmonids, travelling up to 50-100km/day^{-1} to either reach key feed grounds or return to their natal tributaries for spawning opportunities [5]. Natal tributaries support spawning and juvenile life stages. Both Atlantic salmon and Sea trout are commonly associated with long marine migrations, though Arctic charr, is primarily a still-water species, though is occasionally found in river systems.

Adult salmonids usually are found to reproduce in winter months (October - December) and are deemed a rheophilic species (preferring flowing water); the winter months provide cold water temperatures, rich in oxygen which is essential in the reproduction and successful spawning.

Migratory juvenile salmonids can spend between 1-7 years within the riverine / loch system, taking advantage of readily available food resources, increasing fitness, and developing behavioural, morphological, and physiological characteristics to pre-adapt them for migration.

Smolts require specific environmental cues and once prepared physiologically, environmental cues such as temperature and water discharge initiate down-stream migration behaviour. The smolt migration takes place in the spring (Mid-March - May). The timing of migration initiation is vital for migration success and marine environment survival. The smolt migration is believed to be predominately a passive displacement by river currents and alterations to water velocities and direction are likely to have impacts on migrations.

Salmonid species are vulnerable under waterway fragmentation as migration between habitats is essential for completing life stages. The installation and operation of hydro schemes are a cause for concern regarding increased mortality rates seen, particularly in Atlantic salmon and sea trout as the operational phases of hydro schemes can conflict with both upstream and downstream migration patterns for anadromous species. The reason for increased mortality caused by hydro schemes is not always a direct impact of turbine force alone but also includes external factors such as predation due to fish congregating at screens, delayed migration and increased energy expenditure[6]. Most scientific literature on the impacts of hydro schemes on fish relate to conventional hydro electric power stations and not pumped

[1] Scotland's Environment Web. (2022). Search Scotland's Environment Map. [Online] Available at: https://map.environment.gov.scot/sewebmap/ [Accessed 12/12/2022].
[2] Maitland, P. S. (1990) Threats to Britains Native Salmon, Trout and Charr. British Wildlife 5: p.249-261
[3] Scotland, N.B.N.A. (no date) Search for taxa, Species search | NBN Atlas Scotland. Available at: https://scotland-species.nbnatlas.org/ (Accessed: December 13, 2022).
[4] Hendry, K., Cragg-Hine, D., 2003. Ecology of the Atlantic Salmon. English Nature 1–36.
[5] Hansen, L. P. & Quinn, T. P. 1998. The marine phase of the Atlantic salmon (Salmo salar) life cycle, with comparisons to Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 55 (Suppl. 1), 104–118.
[6] Thorstad, E.B., Whoriskey, F., Uglem, I., Moore, A., Rikardsen, A.H., Finstad, B., 2012. A critical life stage of the Atlantic salmon Salmo salar: Behaviour and survival during the smolt and initial post-smolt migration. Journal of Fish Biology 81, 500–542. https://doi.org/10.1111/j.1095-8649.2012.03370.x

storage schemes like Cruachan which differ in operation. There is limited scientific literature currently on the impacts of pumped hydro schemes on fish, however the potential impacts of fish entrainment and impingement and congregation at screens during migration also applies to pumped storage hydro schemes.

3.2.1.2 European eel

Desk study information found a total of six documented records of the European eel within 5km of the Cruachan Reservoir. European eel is a catadromous fish species that spawns in the Sargasso Sea and spends a large proportion of its life in UK freshwaters[7]. Although once highly abundant, a sharp decline in (glass-eel) juvenile recruitment by 90-99% since the 1980's has driven the species to the verge of extinction[8]. Consequently, the European eel is now listed on the IUCN Red List of Threatened Species as "Critically Endangered", just one level above "Extinct in the Wild"[7]. The rapid decline of European eel stock over the last 30 years has been attributed to a variety of anthropogenic threats affecting different stages of the eel life cycle[9].

To prevent further declines and promote recovery of European eel populations, the European Commission created a framework in 2007 (EC 1100/2007), requiring member states to implement eel management plans designed to safeguard the species from anthropogenic threats. Unfortunately, evaluations in 2012 and 2015 have revealed that most participating countries have not reached their intended objectives, with no improvement on eel recovery and little reduction in mortality.

The European eel is listed in the UK Post 2010 Biodiversity Framework and the Scottish Biodiversity List as a 'Priority Species'[10].

[7] De Meyer, J., Ide, C., Belpaire, C., Goemans, G. & Adriaens, D. (2015) Head shape dimorphism in European glass eels (Anguilla anguilla). Zoology, 118, p.413-423

[8] Verhelst, P., Reubens, J., Pauwels, I., Buysse, D., Aelterman, B., Van Hoey, S., Goethals, P., Moens, T., Coeck, J. & Mouton, A. (2018) Movement behaviour of large female yellow European eel (Anguilla anguilla L.) in a freshwater polder area. Ecology of Freshwater Fish, 27, p.471-480

[9] Bevacqua, D., Melia, P., Gatto, M. & De Leo, G. A. (2015) A global viability assessment of the European eel. Global Change Biology, 21, p.3323-3335

[10] Joint Nature Conservation Committee (JNCC) (2012) (UK Post-2010 Biodiversity Framework (2012–2019). Retrieved October 29, 2021, from https://data.jncc.gov.uk/data/587024ff-864f-4d1d-a669-f38cb448abdc/UK-Post2010-Biodiversity-Framework-2012.pdf

4 Existing Mitigation Measures

4.1 Fish Screening

The existing Cruachan Pumped Storage Scheme has screened intakes at Loch Awe and Cruachan Reservoir to prevent the entrainment of fish into the underground waterway system. Downstream migrating salmon and sea trout smolts, which are attracted to outflows whilst migrating through loch systems, may be impacted by the Loch Awe intake area by attraction to the draw of water from the intake resulting in impingement and / or entrainment as they look for the exit of Loch Awe. Fish screens of mesh size **12.5 mm** are currently installed at the intakes. The best practice guide for screening of intakes recommends screen dimensions of ≤12.5mm to protect migratory salmonids from hydro scheme infrastructure[11]. Screens and infrastructure are regularly maintained by Drax for clearance of debris. During the operation of the scheme there has been no evidence of fish mortalities found within the infrastructure (Pers. comm Roddy Davies, Drax, 2023). This would indicate that the screens are effective for excluding fish from the underground waterway system.

4.2 Velocity Control

The existing Cruachan Pumped Storage Scheme operates with controlled water intake velocities during pumping. The maximum velocity approaching the intake screen is **less than 0.3 m/s.**

Attraction towards the screen during abstraction can present delays to migration for fish causing a 'pinch point' where fish are susceptible to predation. This is of particular importance for salmon smolts which are more vulnerable to predation from mammalian, avian and aquatic predators (otter, goosander, cormorant, pike and ferox trout). Any delays to migration caused by anthropogenic effects can also have a negative impact on these species on the timing of their migration to sea as they have evolved to time their downstream migration to reach the sea at the optimum time.

Adult salmonids, conversely, are commonly attracted to turbulent / high velocity waters during upstream migration. Attraction to the outlet are likely to increase delay in upstream migration, potentially resulting in potential mortality due to increased mammalian, avian, or aquatic (otter, cormorant, pike and ferox trout) predation pressures faced at the Loch Awe screen.

The sustained swimming speed of Atlantic salmon for 0.15 m body length is 0.54 m/s[12]. Adult salmon can travel at 0.84 m/s^{-1}. The sustained swimming speed of eels of body length 0.70 m has been shown to be 0.58 m/s with a burst speed of 1.26 m/s.[13] The sustained swimming speed of trout has been shown to be 1.17 m/s. The swimming speed of juvenile lamprey (ammocoetes) is usually between 0.10 and 0.30 m/s[14]. These swimming speeds seem to apply when the lamprey are disturbed or are seeking out food resources. Most larval movement results from passive downstream migration rather than actively moving around. Mature (migratory) sea lamprey of body length 0.58 m have been shown to be capable of moving up to 4.8-5.5 m/s[15]. All of these species therefore have the ability to use escape velocities to voluntarily swim away from the draw of the intake, overcoming the maximum intake velocities of <0.3 m/s. This may not be the case for upstream migrating juvenile European eels (elvers).

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[11] Turnpenny, A.W.H. & O'Keeffe, N. (2005) Screening for Intake and Outfalls: a best practice guide. Available: [Microsoft Word - W6_103 TR _amended__1.doc (publishing.service.gov.uk)]

[12] Tang, J. & Wardle, C. S. (1992) Power Output of Two Sizes of Atlantic Salmon (*Salmo Salar*) at their Maximum Sustained Swimming Speeds. The Journal of Experimental Biology Volume 166. pp. 33-46

[13] Sheridan, S., Turnpenny, A., Horsfield, R., Solomon, D., Bamford, D., Bayliss, B., Coates, S., Dolben, I., Frear, P., Hazard, E., Tavner, I., Trudgill, N., Wright, R. & Aprahamian, M. (2011) Screening at Inlets and Outlets: measures to protect eel (Anguilla anguilla). International Fish Screening Techniques

[14] Maitland, P.S. (2003) Ecology of the River, Brook and Sea Lamprey. Conserving Natura 2000 Rivers Ecology Series No. 5. English Nature, Peterborough

[15] Hoover, J. J. and Murphy, C. E. 2018. Maximum swim speed of migrating Sea Lamprey Petromyzon marinus): reanalysis of data from a prior study. ERDC/TN ANSRP-18-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/ansrp/ansrp.html

Elvers are known weaker swimmers. The sustained swimming speed for an eel of 10 cm body length is 0.13 m/s[16].

5 Proposed Mitigation

It is recommended that the existing mitigation measures as detailed in Section 4. are maintained when the upgrade takes place to retain conditions which suit various salmonid life stages, to reduce potential impacts of entrainment, impingement, injury, increased energy expenditure and / or mortality. Additional mitigation will be required if intake velocities associated with the upgrade are found to be higher than 0.3 m/s (See 5.3). Proposed mitigation measures are described in the context of the upgrade below:

5.1 Continue with the use of Fish Screening:

Continue to implement fish screening using mesh aperture (12.5 mm) to exclude fish from being entrained within the underground waterway system. By screening the inlet / outlet areas this reduces the risk of injury through mortality and / or translocation within the underground waterway system.

5.2 Continue to Implement Velocity Monitoring and Control:

Maintain a maximum inlet velocity at Loch Awe of <0.3 m/s. By reducing velocity, it will further reduce impacts on downstream passively migrating smolts and reduce the likelihood of delaying migrations of adult Atlantic salmon, sea trout, sea lamprey and European eel.

Intake velocity is expected to be similar to the current levels experienced from Units 1 and 2. The exact specification however at this stage is still to be confirmed. It is possible that all four pumps could operate at the same time (Pers. Comm, Roddy Davies, Drax, 2023). If it is found through hydrological monitoring that the cumulative intake velocity across the screens of running all four pumps at the same time is greater than 0.3 m/s, additional mitigation would be required (see Section 5.3).

5.3 Further Mitigation Pending Hydrological Monitoring

If hydrological monitoring finds that the cumulative intake velocity across the screen whilst running all four pumps is greater than 0.3 m/s, additional mitigation would be required to protect fish from the impacts of entrainment and / or impingement at the fish screens. It is understood that the intake velocity of Units 1 and 2 is 0.24 m/s and that the upgraded Units 3 and 4 are likely to have a similar velocity. If hydrological studies find that the cumulative intake velocity whilst running all four pumps at the same time is greater than 0.3 m/s, further mitigation measures will be explored, which may include avoiding the running of all four pumps at the same time during sensitive annual smolt migration periods (mid-March – end May).

[16] Sheridan, S., Turnpenny, A., Horsfield, R., Solomon, D., Bamford, D., Bayliss, B., Coates, S., Dolben, I., Frear, P., Hazard, E., Tavner, I., Trudgill, N., Wright, R. & Aprahamian, M. (2011) Screening at Inlets and Outlets: measures to protect eel (*Anguilla anguilla*). International Fish Screening Techniques Available: Microsoft Word - Sections_IFS.docx (witpress.com)