MOTT MACDONALD

Loch Earba PSH

Impact on flows upstream of Loch Pattack

Project:	Loch Earba PSH		
Our reference:	100112953/04/B	**Your reference:**	<Insert Text>
Prepared by:	[redacted]	**Date:**	28 January 2025
Approved by:	[redacted]	**Checked by:**	[redacted]
Subject:	Impact of Loch Leamhain works on flows upstream of Loch Pattack		

1 Introduction

This technical note assesses potential changes to flows along the Allt Leamhain and Allt Cam due to the planned installation of cut off ditches within the proposed dammed catchment of Loch Leamhain, which holds the upper reservoir of the Earba Pumped Storage Hydropower scheme. Cut off ditches within the Loch Leamhain catchment are being proposed to allow a proportion (50%) of the Leamhain catchment to feed downstream into the Allt a Bhealaich Leamhain and Allt Cam and avoid transfer of water from the Earba catchment into the Pattack catchment via the PSH scheme. This is to mitigate against the transfer of Invasive Non-Native Species.

2 Simulated changes to Allt Leamhain and Allt Cam Flow duration Curves

2.1 Modelling approach

2.1.1 Existing catchment flows

2.1.1.1 Flow assessment points overview

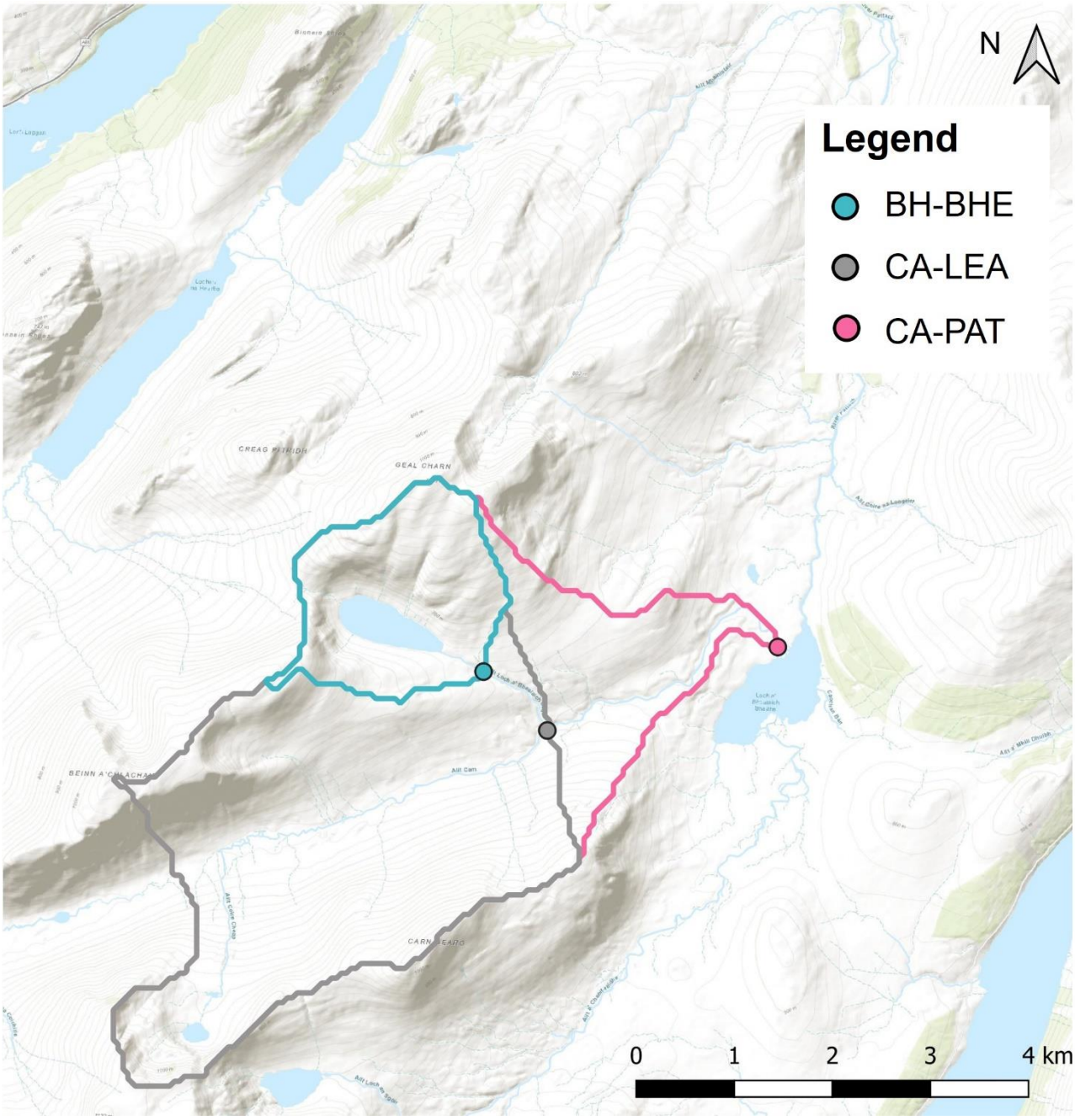
Existing and proposed flows were assessed at three locations (Table 2.1 and Figure 2.1).

Table 2.1: Flow assessment point locations

Catchment code	Description	Easting	Northing	FEH area (km^2)
BH-BHE (dammed)	Allt Leamhain immediately downstream of Leamhain Dam and cut off ditches	250900	779200	3.6

Catchment code	Description	Easting	Northing	FEH area (km^2)
CA-LEA	Allt Cam immediately downstream of Allt Leamhain confluence	251550	778600	15.6
CA-PAT	Allt Cam at inflow to Loch Pattack	253900	779450	19.02

Figure 2.1: Map of flow assessment locations



2.1.1.2 Climate data

Catchment average daily rainfall, temperature and PET time series were estimated for the catchments associated to each of the three location assessment points (Figure 2.1). The approach for estimating catchment climate data was as follows:

- BH-BHE (dammed) – assumes the HadUK rainfall, temperature and PET series previously extracted for the natural catchment of Loch Leamhain (250550 East, 779400 North; 2.6km^2) (Mott MacDonald, 2024);
- CA-LEA – scaled from the HadUK rainfall, temperature and PET data for the Pattack catchment (254900 East, 783300 North; 64.5km^2) (Mott MacDonald, 2024); and
- CA-PAT – scaled from the HadUK rainfall, temperature and PET data the Pattack catchment (254900 East, 783300 North; 64.5km^2) (Mott MacDonald, 2024).

This approach does not give precisely the same results as would be found be rederiving data series from HadUK for the new catchments, but in terms of assessing prospective changes to the FDCs any differences would not be significant.

Information regarding which previously derived climate series were used to determine the climate data for the flow assessment locations is provided in Table 2.2, along with the scaling factors applied.

Table 2.2: Climate data scaling factors

Flow assessment catchment	Donor catchment	Rainfall scale factor	Temperature scale factor	PET scale factor
BH-BHE (dammed)	BH-BHE (natural) (i.e., Loch Leamhain natural catchment)	1	1	1
CA-LEA	PA-PAT (i.e., Pattack catchment at stream gauging location)	1.046	0.914	0.968
CA-PAT	PA-PAT (i.e., Pattack catchment at stream gauging location)	1.033	0.953	0.979

The scaling factors in Table 2.2 were derived by comparing estimates of annual average rainfall, average temperature, and annual average PET for the flow assessment catchments to those of the donor catchments. For the donor catchments these climate indices were estimated as part of the previous hydrology work using HadUK data (Mott MacDonald, 2024). Climate indices for the flow location catchments were estimated using relationships with elevation established from the Loch Earba, Loch Leamhain and Pattack catchments of the main report (Mott MacDonald, 2024).

Figure 2.2: Mean annual precipitation to elevation relationship

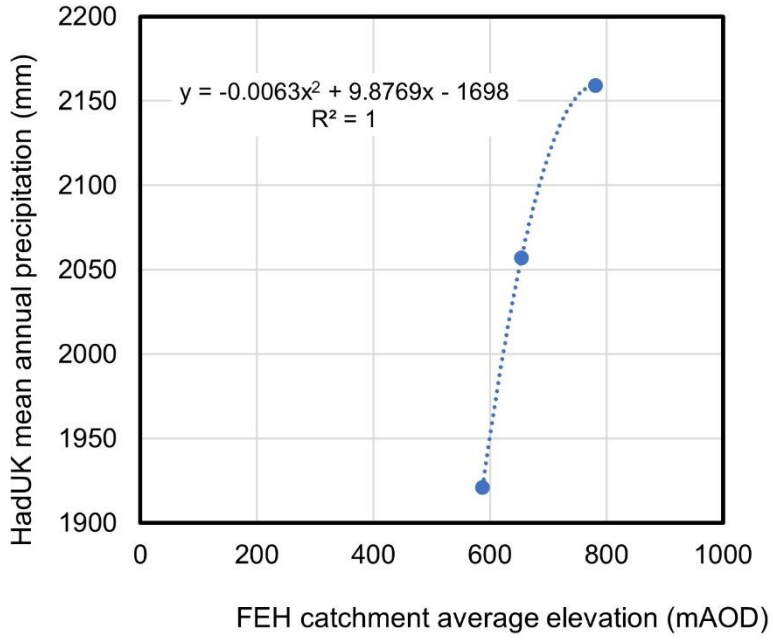


Figure 2.3: Mean temperature to elevation relationship

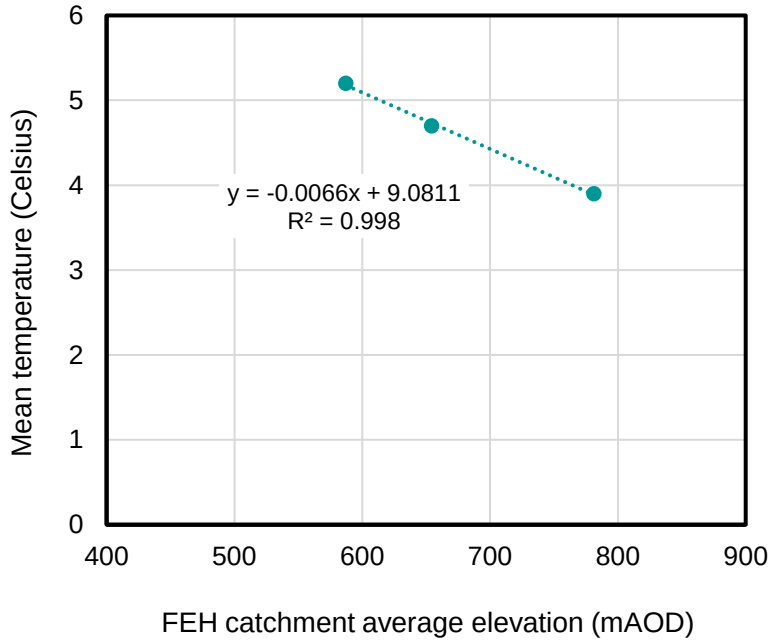
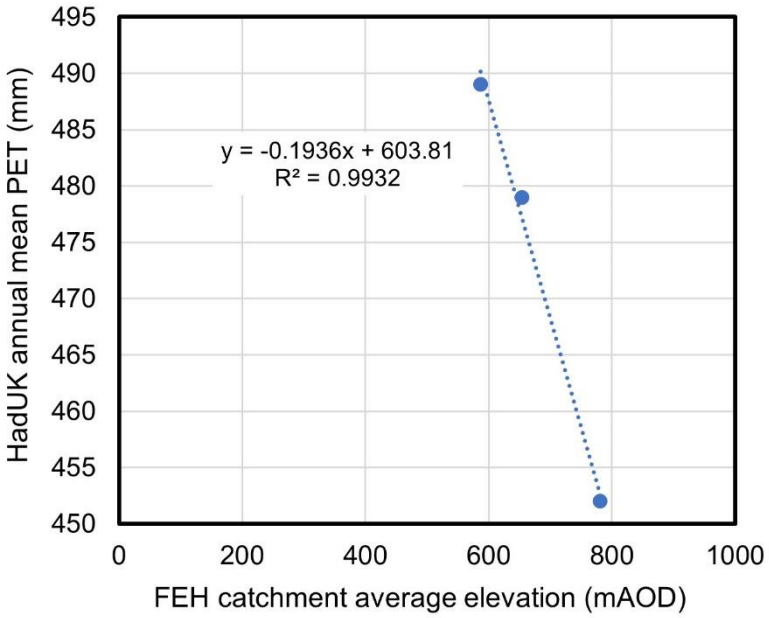


Figure 2.4: Mean annual PET to elevation relationship



2.1.1.3 Flow simulation

Flows were simulated for each catchment using GR6J for the full data period (1891-2021). However, further analysis only used flows for the period 1960-2021 (in keeping with the main study) as data before 1960 is considered less reliable and less likely to be representative of current or near-future conditions.

2.1.2 Proposed catchment flows

Cut off channels within the dammed Loch Leamhain catchment will divide the catchment into two parts, an upper catchment (1.8km^2) and lower catchment (1.8km^2). Runoff from the upper fraction of the catchment will be diverted downstream into Allt Leamhain and will not contribute towards the filling of Loch Leamhain. The lower fraction of the catchment (much of which comprises the reservoir surface) will runoff into Loch Leamhain and interact with the Earba PSH scheme and not flow downstream into Allt Leamhain.

With this knowledge, flows at the three assessment locations with the proposed cut off ditches in place were calculated as follows:

- BH-BHE update – scaling the existing flows at this location by 50%, according to the fraction of the catchment which is diverted into the channel by the cut off ditches;
- CA-LEA – subtracting the fraction of BH-BHE update flows that drain into Loch Leamhain from the existing CA-LEA flows; and,
- CA-PAT – subtracting the fraction of BH-BHE update flows that drain into Loch Leamhain from the existing CA-LEA flows.

2.2 Results

Expected changes to flows at the three assessment locations due to the proposed installation of cut off ditches within the dammed Loch Leamhain catchment are highlighted by flow duration curves in Figure 2.5,

Figure 2.6 and Figure 2.7 and tabulated in Table 2.3 and Table 2.4. Findings are presented in litres per second but it would be reasonable to regard them to the nearest 10l/s.

In absolute terms, the changes in flow at each of the three locations is the same. This is because the proposed flows at each location are calculated by subtracting the flows in the dammed loch Leamhain catchment that will continue to drain into Loch Leamhain from the existing flows. However, in relative terms, the proposed cut off ditches in the dammed Loch Leamhain catchment substantially alter the flows in Allt Leamhain (BH-BHE update) but not in Allt Cam either immediately downstream of the confluence with Allt Leamhain (CA-LEA) or at its inflow into Loch Pattack (CA-PAT).

Figure 2.5: Existing and proposed flow duration curve – BH-BHE update

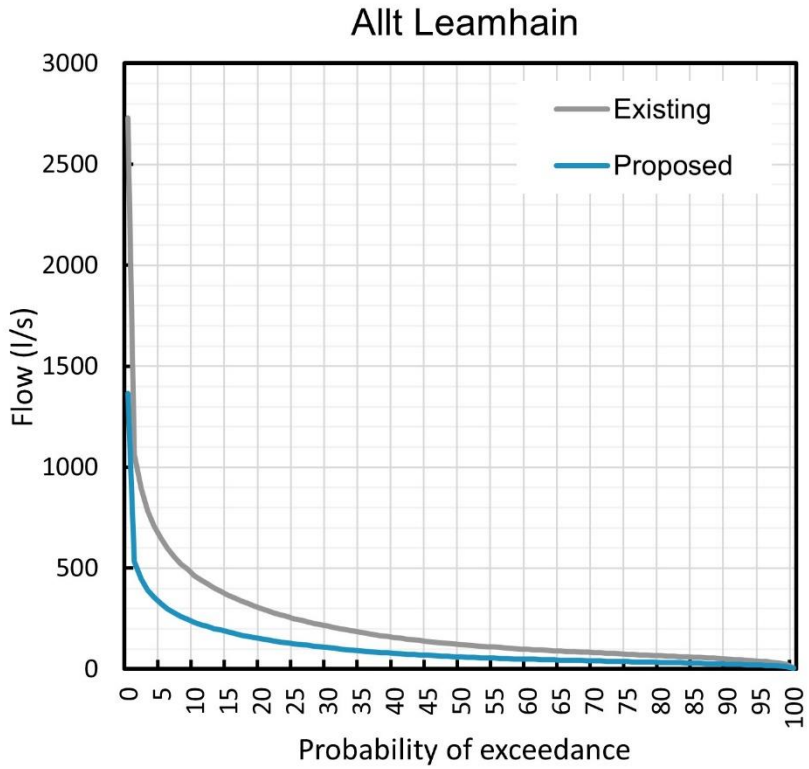


Figure 2.6: Existing and proposed flow duration curve – CA-LEA

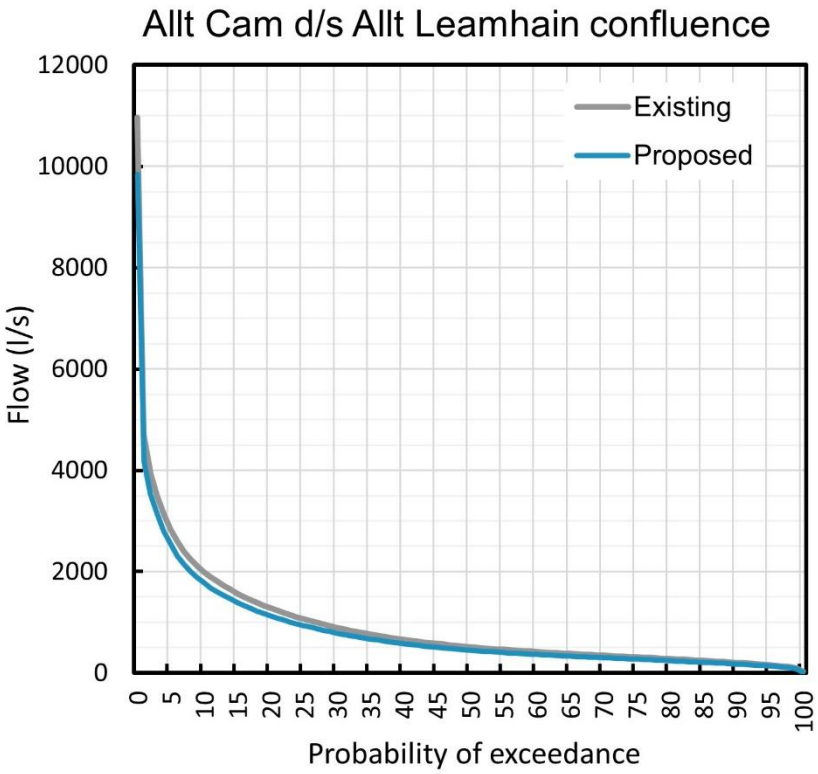


Figure 2.7: Existing and proposed flow duration curve – CA-PAT

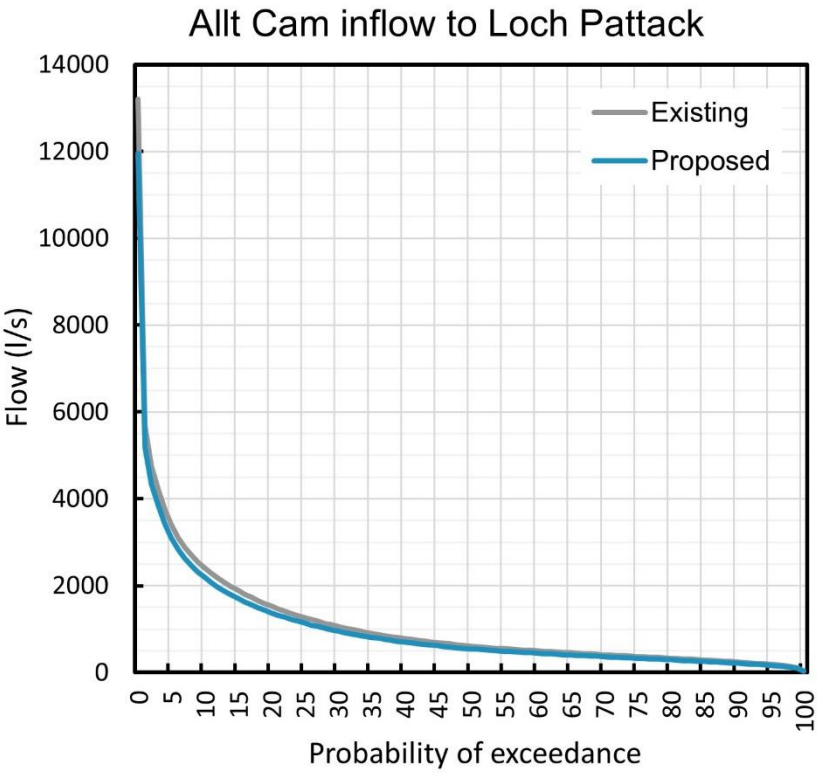


Table 2.3: Flow duration curves – existing flows (l/s)

	BH-BHE update	CA-LEA	CA-PAT
Q99	24	91	107
Q95	39	158	185
Q90	50	204	241
Q80	67	278	329
Q70	81	345	409
Q60	98	418	497
Q50	121	511	608
Q40	156	657	781
Q30	213	895	1,061
Q20	301	1,280	1,527
Q10	463	1,998	2,399
Q5	647	2,838	3,407
Q1	1,062	4,698	5,680

Table 2.4: Flow duration curves – proposed flows (l/s)

	BH-BHE update	CA-LEA	CA-PAT
Q99	12	78	92
Q95	20	136	163
Q90	25	176	211
Q80	34	240	291
Q70	41	300	364
Q60	49	365	444
Q50	61	448	544
Q40	78	576	700
Q30	107	785	950
Q20	151	1,129	1,375
Q10	232	1,782	2,184
Q5	323	2,545	3,104
Q1	531	4,177	5,186

3 Gauged and simulated changes to Allt Leamhain and Allt Cam Flow Duration Curves

Recent gauging by MNV Consulting Ltd (MNV Consulting Ltd, 2024) provides an opportunity to assess the impacts of the proposed cut-off channels within the dammed Loch Leamhain to downstream flows on Allt Leam and Allt Cam (Section 2) using the gauged flow data for the dammed Loch Leamhain. This can subsequently be compared to the findings determined using Loch Leamhain flows simulated with GR6J.

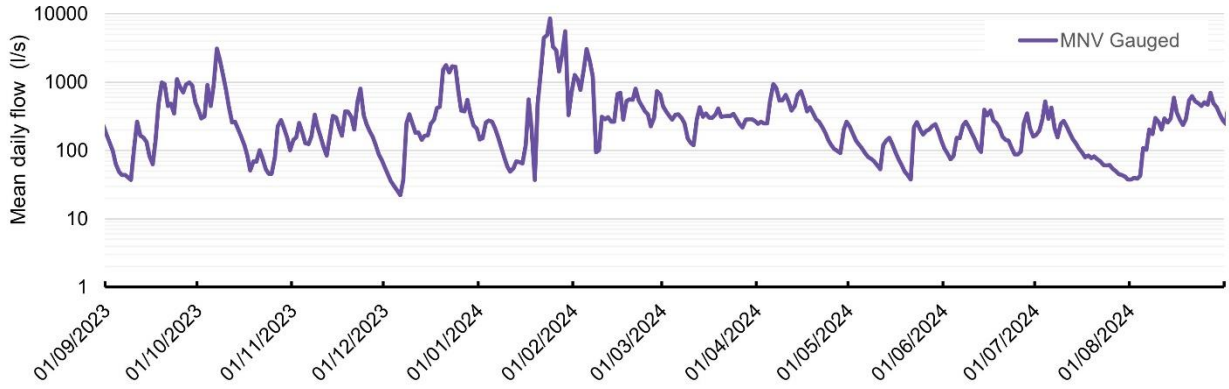
3.1 Approach

The approach follows that outlined in Section 2.1.2 but substitutes simulated flows for the proposed Loch dammed catchment with those recorded by MNV. To make a fair comparison of the influence of using either gauged or simulated Loch Leamhain flows to downstream flows along the Allt Lemahain and Allt Cam, the assessments should be made for the same time period.

3.1.1 MNV gauged flows for Loch Lemhain outflow (September 2023 – August 2024)

The recent MNV gauging on Allt Leamhain at the outfall of the proposed Leamhain Dam provides 15-minute flow data between the 29th of June 2023 to the 15th of October 2024. The annual record from the 1st of September 2023 to 31st of August 2024 (Figure 3.1) is used to assess the potential downstream impacts to flows along the Allt Leamhain and Allt Cam due to the planned installation of cut off ditches within the Loch Leamhain catchment.

Figure 3.1: Gauged mean daily flow time series – proposed dammed Loch Leamhain catchment



Source: Adapted from (Mott MacDonald, 2025)

3.1.2 Extension of simulated flows (September 2023 – Augst 2024)

As discussed in Section 2, simulated flows for the Allt Cam immediately downstream of Allt Leamhain confluence (CA-LEA) and for the Allt Cam at the inflow to Loch Pattack (CA-PAT) were determined for the period from 1891 to 2021 using the Pattack catchment to transfer GR6J hydrological model parameters and to scale climate data inputs from. Extended climate and simulated flows series up to the end of 2024 are not readily available for the Pattack catchment. However, as part of the comparison between simulated and gauged outflows for Loch Leamhain (Mott MacDonald, 2025), simulated flows for the proposed dammed catchment of Loch Leamhain were extended to the 31st August 2024. However, it should be noted that the HadUK rainfall and temperature data for 2024 is provisional (based on a limited number of gauges) and will be revised when full 2024 data becomes available later in 2025.

Therefore the 2024 extended flow series for Loch Leamhain is used to determine differences in the flow duration curve for the initial assessment period of 1960-2021 and the annual period (September 2023-August 2024) aligning with the MNV gauged record and used for this assessment. The comparison provides percentile-wise scale factors to adjust the 1960-2021 flow duration curve to a flow duration curve representative of September 2023-August 2024. These scale factors were used to adjust the flow duration curves for CA-LEA and CA-PAT to the September 2023-August 2024 annual period.

3.1.3 Proposed catchment flows

In line with the previous assessment using simulated flows, the proposed flows not diverted downstream from the dammed Loch Leamhain catchment were determined by scaling the gauged flows at this location by 50% (the fraction of catchment diverted downstream by cut of channels).

The flow duration curve of the proposed flows not diverted downstream of Loch Leamhain under the scheme is directly subtracted from the flow durations for CA-LEA and CA-PAT under existing conditions to determine the proposed flow duration curves at these downstream locations with the scheme in place. Flow duration curves were directly subtracted from one another as flow time series were not available for CA-LEA and CA-PAT for the assessment period. This approach is considered reasonable as the hydrological models developed for the Earba scheme all use the same model parameters calibrated for the Pattack catchment and climate data inputs are highly correlated (Mott MacDonald, 2024).

3.2 Results

Figure 3.2 shows the simulated flow duration curve for the dammed catchment of Loch Leamhain over the period from 1960 to 2021 and compares it to the catchments flow duration curve between September 2023 and August 2024. Comparing the flow duration curves on a percentile-wise basis provided the scale factors used to adjust the CA-LEA and CA-PAT flow duration curves to the more recent annual period.

Figure 3.2: Flow Duration Curve adjustment for 2023-2024 period – BH-BHE_update

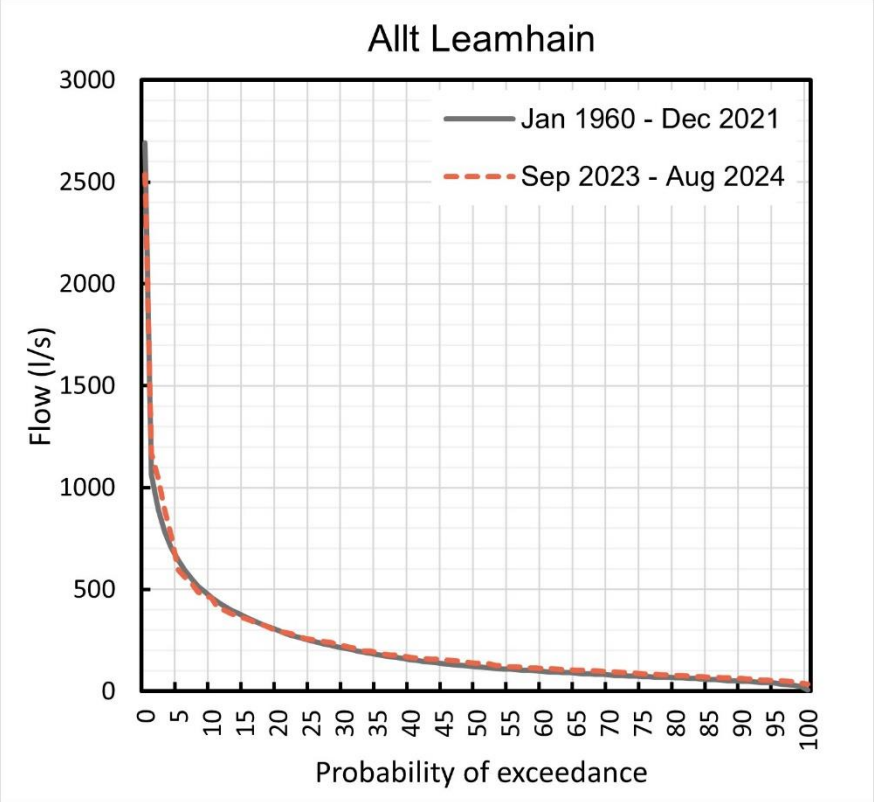


Figure 3.3, Figure 3.4 and Figure 3.5 show the expected changes to flows at the three assessment locations due to the proposed installation of cut off ditches. Moreover, they compare the changes made to flow duration curves when using either simulated or gauged flows for the outfall of the proposed dammed Loch Leamhain catchment. Findings are also tabulated in Table 3.1, Table 3.2 and Table 3.3. Findings are presented in litres per second but it would be reasonable to regard them to the nearest 10l/s.

For the September 2023 - August 2024 assessment period, gauged flows for the dammed catchment of Loch Leamhain are on average 86% greater than those simulated by GR6J. This is further highlighted in Figure 3.3 which compares the simulated and gauged flows for the catchment. As previously mentioned, the outflows from the catchment under the proposed Pumped Storage Hydropower scheme will be 50% of the existing catchment outflow flows. On average this equates to a reduction in flows of approximately 205l/s using the gauged data and 110l/s using the simulated flows. Therefore, using the gauged record to assess the impacts of the scheme to downstream flows at the Allt Cam-Allt Leamhain confluence and on the Allt Cam at its inflow to Loch Pattack will generate a slightly larger reduction in flows in comparison to using simulated flows. Nonetheless, these differences are only expected to be minor (Figure 3.4 and Figure 3.5) as the dammed catchment of Loch Leamhain contributes a relatively small proportion of the total catchment flows at these downstream locations.

Figure 3.3: Existing and proposed flow duration curve – BH_BHE_update

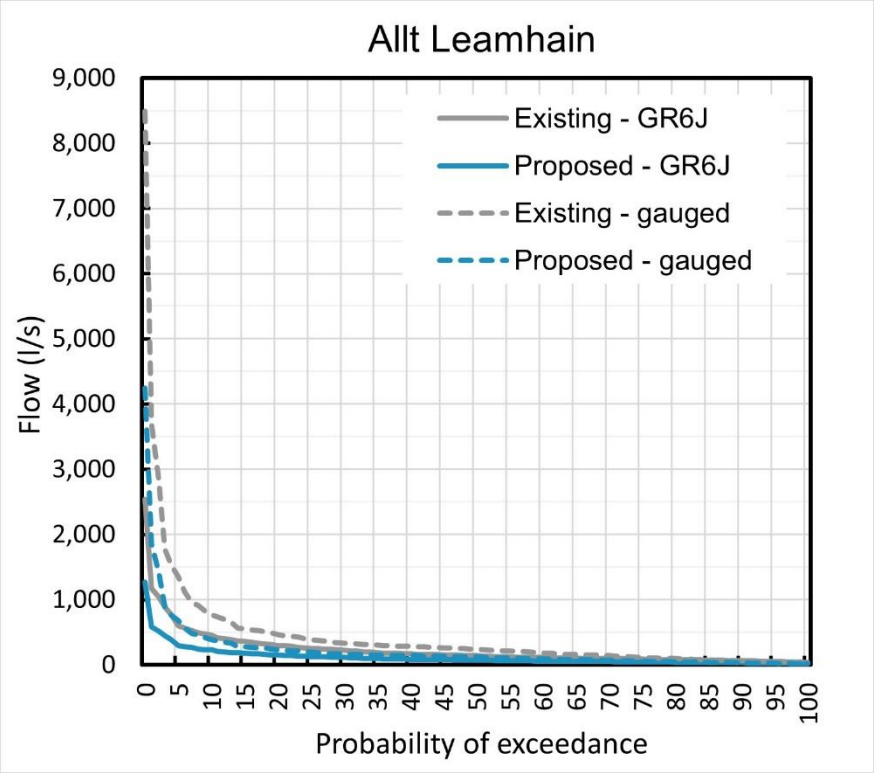


Figure 3.4: Existing and proposed flow duration curve – CA-LEA

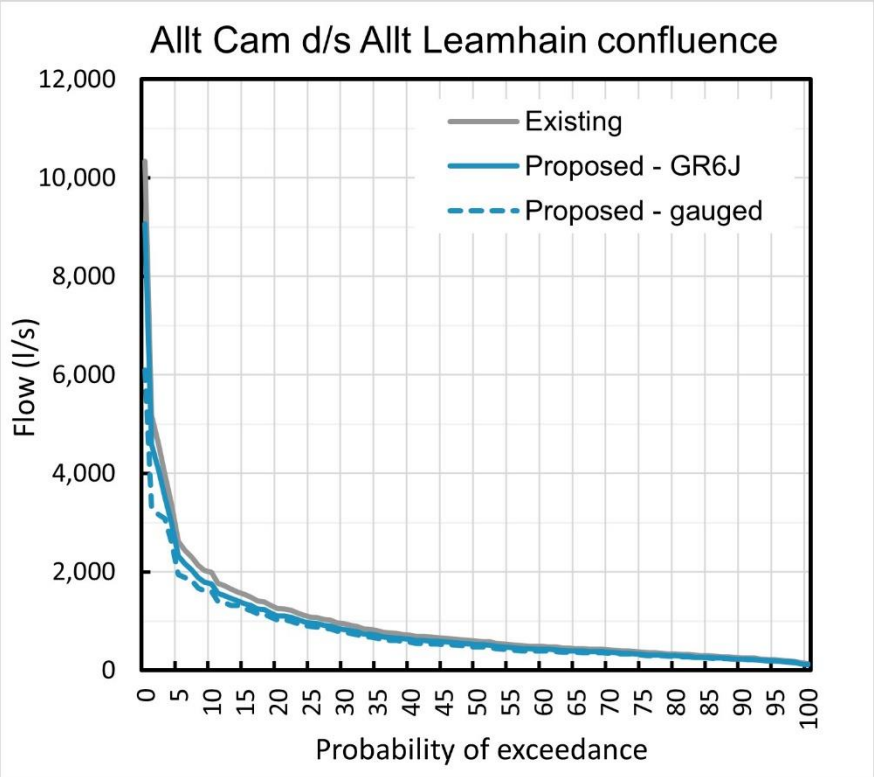


Figure 3.5: Existing and proposed flow duration curve – CA-PAT

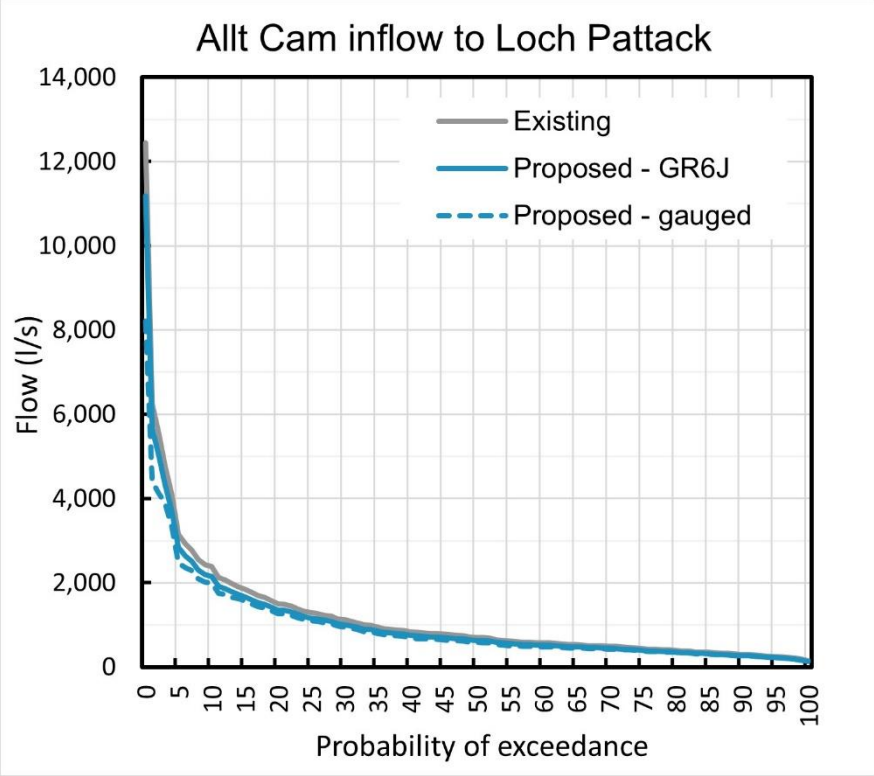


Table 3.1: Existing and proposed flow duration curves – BH-BHE_update (l/s)

	Existing - gauged	Proposed – gauged	Existing – simulated	Proposed – simulated
Q99	36	18	40	20
Q95	44	22	52	26
Q90	61	31	62	31
Q80	94	47	79	40
Q70	141	70	98	49
Q60	181	90	113	57
Q50	243	121	139	70
Q40	281	141	167	84
Q30	334	167	224	112
Q20	464	232	294	147
Q10	772	386	458	229
Q5	1349	675	594	297
Q1	3691	1845	1169	584

Table 3.2: Existing and proposed flow duration curves – CA-LEA (l/s)

	Existing	Proposed – gauged	Proposed – simulated
Q99	153	135	133
Q95	212	190	186
Q90	253	222	222
Q80	333	286	293
Q70	415	345	367
Q60	482	392	425
Q50	592	471	522
Q40	708	567	624
Q30	946	779	834
Q20	1,254	1,023	1,107
Q10	1,985	1,599	1,756
Q5	2,615	1,941	2,318
Q1	5,169	3,324	4,585

Table 3.3: Existing and proposed flow duration curves – CA-PAT (l/s)

	Existing	Proposed – gauged	Proposed – simulated
Q99	180	162	160
Q95	248	226	222
Q90	299	268	268
Q80	394	347	354
Q70	492	422	444
Q60	573	483	517
Q50	704	583	635
Q40	841	701	758
Q30	1,121	954	1,009

	Existing	Proposed – gauged	Proposed – simulated
Q20	1,496	1,265	1,349
Q10	2,383	1,998	2,154
Q5	3,140	2,465	2,843
Q1	6,250	4,405	5,666

4 Summary

Flow duration curves have been produced through rainfall-runoff modelling for three locations for the current condition and for the proposed future condition when the Earba scheme is in operation. Flows downstream of Loch Leamhain will be reduced because rainfall on the reservoir surface and that on land immediately surrounding the reservoir will be retained in the reservoir.

There is a significant impact in Allt Leamhain immediately downstream of the proposed new dam but only minor impact in Allt Cam. Further testing the potential impacts to downstream locations along the Allt Cam using the gauged flow record for the Loch Leamhain catchment does not substantially change these findings.

5 References

Mott MacDonald, (2024). Hydrology study: Loch Earba PSH (Rev D)

Mott MacDonald, (2025). Loch Earba PSH: Comparison of model simulations to gauged data (Rev C)

MNV Consulting Ltd, (2024). Hydrology of the Allt Loch a 'Bhealaich Leamhain