Glen Earrach

Technical Clarification on Flood Risk

Dear SEPA and The Highland Council (THC),

Electricity Act 1989
Town and Country Planning (Scotland) Act 1997
The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017

Glen Earrach Energy Pumped Storage Hydro (PSH) Project
Technical Clarification SEPA and THC Flood Risk Management Team – October 2025
ECU Ref: ECU00005121
SEPA Ref: PCS-20006092

Following the submission of technical clarifications for Glen Earrach Pumped Storage Hydro (the Proposed Development) to respond to the Scottish Environment Protection Agency (SEPA) and The Highland Council (THC) Flood Risk Management Team, in September and October 2025 respectively, a joint call was held with those teams and the Applicant's planning and hydrology teams, on Thursday 9 October 2025, to discuss the concerns raised by SEPA and THC.

The following topics were identified in the meeting as potentially benefiting from additional technical clarification from the Applicant:

1. Quantification, at least in outline terms, of the potential flood risk introduced by the separate Dochfour Weir Upgrade works, covering summer flood events (to allow these works to then be secured through a Planning Condition to the Proposed Development);
2. Provide further clarity on the potential impact to downstream receptors (along River Ness) from the Proposed Development; and
3. Clarification of the proposed stop generating level.

This technical clarification response, together with accompanying Technical Note, sets out to address these points and demonstrate that the Proposed Development is aligned and compliant with Policy 22 – Flood Risk and Water Management of National Planning Framework 4 (NPF4).

Overall Position of the Applicant with Respect to Flood Risk

Before discussing the detail of the concerns, it is considered important to clarify the Applicant's position with respect to the design of the Proposed Development insofar as it relates to flood risk.

The introduction of additional storage into the Ness catchment through Pumped Storage Hydro (PSH), which does not represent an impoundment of natural inflows but simply stores water, has the potential to significantly assist with flood alleviation for Loch Ness, the River Ness and Inverness. Operation of PSH in this manner, to provide flood alleviation benefits, is considered state of the art within the large hydropower industry globally, and represents one of the societal benefits, beyond the monetary and climate change benefits provided through its interaction with the electricity grid.

Achieving flood alleviation involves an integrated operation between different water users (in particular if there are multiple PSH) supported by existing or potentially augmented flood forecasting. Successful flood alleviation is an achievable goal, but to deliver on this requires a coordinated approach between all stakeholders. This overriding principle of coordination of Loch Ness stakeholders and PSH operators is part of the reason that the Applicant has proposed that a Water Management Board be established covering water operations on Loch Ness, to ensure this potential benefit to local communities can be maximised.

The Applicant fully agrees with the statements by both SEPA and THC that operation of the Proposed Development should have no impact on downstream flood receptors. The Applicant would further quantify this in terms that neither the magnitude nor frequency of flooding to downstream receptors should be increased through operation of the Proposed Development. As set out above, the Applicant sees an opportunity to achieve an improvement to the baseline, and this should be an objective of the Proposed Development, including the additional Dochfour Weir Upgrade works that would come as a separate planning application, to be secured through an appropriate planning condition to the Proposed Development.

Basis of Assessment

As has been set out, in the Section 36 Application for the Proposed Development and subsequent Additional Information and technical clarifications, an identified mitigation for the Proposed Development is the Dochfour Weir Upgrade. This would allow for variable level control during the summer months. In addition to that mitigation, it would enable other benefits including improved fish passage and the potential for flood alleviation improvements. Further details on this have been provided in the Application, Additional Information and technical clarifications.

It has been proposed by the Applicant that the Dochfour Weir Upgrade works be secured through two Planning Conditions that would be attached to the Proposed Development's consent. Firstly, that planning consent for the Dochfour Weir Upgrade is granted prior to commencement of the Construction Phase of the Proposed Development. Secondly, that the Dochfour Weir Upgrade works are to be completed and commissioned prior to the Operational Phase and full energisation.

With respect to the overall question of flood risk, both for the Proposed Development, and for the Dochfour Weir Upgrade works (as proposed in Appendix 2.1), the Applicant considers that the assessments that have been undertaken and the information that has been provided are sufficient to assess the impact of the Proposed Development. As has been stated above, the Applicant agrees there should be no negative impacts, and all assessments for the Proposed Development to date have sought to demonstrate this. There is a balance between the information required for SEPA and THC to properly understand the impact of the Proposed Development at this stage of the consenting process, in order to make their representation to the Scottish Ministers, and the information that will be required for the CAR licensing process. As such, the Applicant considers that for the purposes of the consultee responses from SEPA and THC, it is necessary to demonstrate an overall viability and level of impact of the Proposed Development with respect to flood risk.

The flood risk from the Proposed Development is a function of its operation and the proposed water use, i.e. the abstraction and discharge activities. It does not arise from the physical development. The CAR licensing process is the means by which the Proposed Development's use of water, and impact on the water environment, will be considered in more detail and subject to statutory control. The detailed operational parameters, which secure the modelled flood performance is therefore a consideration for the CAR licensing process. It is not practical to address the full details required for the CAR licensing process as part of the Section 36 application. This in part relates to the need to consider the Dochfour Weir Upgrade operations as part of any such operations assessment, and to also include for the co-ordination between PSH operators, which is proposed to be achieved through the establishment of the Water Management Board. The Applicant accepts that flood risk is an important consideration in the determination of the Section 36 application. However, the existence of a separate regulatory process to control the use of the Proposed Development to protect against that risk is an equally important consideration. There is a body of case law confirming that where an overriding licensing condition exists (as with the CAR licence), the planning process (or in this case the Section 36 consent process) is concerned with understanding the overall development impacts and the feasibility of delivering them. The detailed control of those matters is left to the separate licensing control (CAR).

Of equal importance, the above is simply a practical reflection on how the detailed operational parameters necessary to carry out an updated flood risk assessments need to take account of the CAR licenses of other schemes. Coupled with the details of the Dochfour Weir Upgrade and including any agreed objectives for flood alleviation measures. For example, these may include the operation of the Dochfour Weir Upgrade during winter months to achieve flood alleviation (not related to PSH activity), but this is not required as a core mitigation for the Proposed Development. For the extended operation of the Dochfour Weir Upgrade, this would need a fully coordinated approach using a Water Management Board, where the discussions on which only become a practical possibility once consent is secured for the Proposed Development and any other PSH in the catchment at that time.

It is proposed by the Applicant that any concerns in this regard can be secured through Planning Conditions, including setting out requirements that there shall be no increase to the flood risk to downstream flood receptors. The Applicant further considers that the need for an updated flood risk assessments is best handled through the CAR licensing process and secured through a Planning Condition to the Proposed Development as CAR will evolve this matter so flexibility is key.

At the conclusion of this document, the document sets out the principles of proposed planning conditions to address the concerns, with the objective of providing additional comfort to SEPA and THC on the Proposed Developments approach to handling flood risk and enable them to respond to Scottish Ministers as a statutory consultee.

Potential Impact to Downstream Receptors

The Applicant's approach for the Proposed Development's flood risk assessment has been to avoid any change to the frequency or exceedance of the flood limit of 600 cumecs through the way in which the scheme is operated. It is observed the 600 cumecs threshold matches the CAR license issued for the Loch na Cathrach scheme.

The Applicant agrees with both SEPA and THC that the operation of PSH should not increase risk of floods to downstream receptors with respect to existing behaviour of the Loch Ness, taking account of existing CAR licenses. As such, the Applicant proposes to include this as an overriding condition for the Proposed Development. This Planning Condition would in effect supersede the 600 cumecs, representing a more fundamental obligation on the Proposed Development, which would be demonstrated through the submission of an updated flood risk assessment as part of the CAR licensing process, as explained above.

The Applicant's modelling included in the submitted flood risk assessment has demonstrated no negative impact, based on the way in which the generating profile rationally aligns to flood events. This includes evidence showing that the flood peak is mitigated by initiating pumping before the peak of the flood, addressing one of the questions previously raised by THC about the 2014 results.

Concern has been raised by THC regarding a worst-case scenario of full generation just prior to the peak of a flood event. This concern logically applies to any 'stop generating level' established under the CAR licensing process for any PSH scheme. While the Applicant's model for operations does not create this effect; it is considered such a scenario is highly unlikely (going against the way the Applicant's model responds to such a situation). It is considered that protection against this scenario could be handled within, and formalised as part of, the CAR license, such that no such event can take place, i.e. that generation is curtailed in the event of a flood warning, and that a restriction is established through the CAR license to prevent any such operation.

It is considered that the simplest way this could be achieved would be through a 'flood-mode recharge level', set lower than the 'stop-generating level' and initiated in a flood warning scenario (for example 16.9m versus a normal higher stop generating level). In such a scenario, the Applicant would be obligated to start recharging the upper reservoir through pumping in advance of the peak of the flood, offering benefits of flood mitigation to the catchment. The extensive attenuation period provided in Loch Ness results in a significant lag between the flood peak in Loch Ness inflows and that of the Loch Ness and downstream, makes this a particularly robust approach. Of course, any such flood operation would need to be coordinated with all PSH CAR licenses to ensure alignment of their trigger levels (to avoid one PSH pumping while another is still generating). It is considered that this state-of-the-art coordinated approach to mitigate floods is best achieved through the CAR licensing process as noted above and uses a Water Management Board.

Clarification of the Proposed Stop Generating Level

It is acknowledged there is scatter associated with the level in Loch Ness, which corresponds to the identified flow limit of 600 cumecs. It is further noted a level of 17.1 m has been identified as equivalent for the Loch na Cathrach scheme. The Applicant confirms the agreement that the 17.44 m proposed should be reviewed as part of the CAR license process to ensure a consistent level is adopted, which gives confidence to flood management authorities. The Applicant has carried out a sensitivity analysis of the Proposed Development's operations (including the cumulative position with all other existing and proposed PSH) and have considered hands-off 'stop-generating' levels even down to 16.9m as having a negligible impact on operations. As such, the Applicant feels comfortable that the correct determination of this level as part of the CAR license does not put the Proposed Development at risk.

Recognising the scatter in the existing rating of the Dochfour Weir, the Applicant proposes to offer a Planning Condition as part of the Dochfour Weir Upgrade that a precise rating is established for the Dochfour Weir Upgrade in cooperation with SEPA and THC. It is considered this will be both necessary as part of the Dochfour Weir Upgrade works and will also provide an overall benefit to the management of the catchment and downstream flood risks.

Quantification of flood risk from the Dochfour Weir Upgrade

Another concern that has been raised relates to the potential impact of summer operations of the Dochfour Weir Upgrade on flood risk. Specifically, if a short-notice summer flood event took place with the Dochfour Weir Upgrade in a fully raised condition[1]. While the flood risk assessment for the Dochfour Weir Upgrade will need to

[1] In the provided technical clarifications, it is confirmed that no winter operation is considered for the Dochfour Weir Upgrade as a mitigation for the Proposed Development. Winter operation may be considered of interest for flood management purposes as part of overall flood resilience measures, but

form a part of the Dochfour Weir Upgrade standalone planning application and CAR license application; it is recognised that the importance of assessing a range of scenarios to give comfort at this stage. Therefore, the Applicant has modelled a series of summer flood scenarios, up to and including a 1 in 200 year + climate change scenario, to demonstrate the potential impact if a flood event was to occur without advanced warning. The results of this analysis are included as an attachment.

The results demonstrate, both with the Proposed Development in isolation and considering the cumulative situation with all existing and proposed schemes (Foyers PSH, Loch Kemp Storage and Loch na Cathrach) using the Dochfour Weir Upgrade, that the baseline flood flows in River Ness are not exceeded. Therefore, representing no increase of risk to downstream receptors. At the same time, if no action is taken by the Proposed Development (i.e. no pumping) a modest rise in Loch Ness is seen but not beyond 17.67m (compared to a baseline of 17.43m, considering a 1 in 200 year summer event + climate change event). If pumping is initiated by the Proposed Development at the time of the flood, even with only 50% pumping capacity, the peak level of a 1 in 200 year summer event + climate change event is mitigated below that of the baseline condition. In the case of all schemes (existing and proposed), similar results are seen, and again demonstration is provided in the attachment how peak levels and flows can in fact be mitigated by strategic use of the PSH assets.

These results demonstrate the limited risk associated with the summer operation of the Dochfour Weir Upgrade (no impact on downstream receptors, no damaging impact on Loch Ness perimeter), while also demonstrating the benefits of using the PSH as a flood alleviation option in case of any flood event (reducing the Loch Ness levels and River Ness flows below the baseline flood condition). Through the Water Management Board, the Ness catchment could be a global leader in this approach, with flood alleviation through coordination of PSH representing state-of-the-art use of the technology.

Proposed Updated Conditions to the Development

Based on the discussions held with SEPA and THC, the concerns raised, and the Applicant's technical clarifications provided, it is proposed the following principles are used to forge a suite of additional or modified conditions to the Proposed Development:

1. The stop generating level is to be established, in consultation with THC, as part of the CAR licensing process for the Development, with the CAR license dependent on the updated Flood Risk Assessment to be included as part of the Dochfour Weir Upgrade CAR application, and therefore taking account of the operation of the modernised Dochfour Weir Upgrade. This condition will include the Applicant providing an update of the level-discharge curves for the Dochfour

that would be a matter for the Dochfour Weir Upgrade and would depend on this being something of interest to THC, SEPA and other stakeholders, potentially through a Water Management Board.

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Weir Upgrade to the satisfaction of SEPA and THC (updated from that provided by the Loch Dochfour Reservoirs Act Section 10 Inspection Report 1987).

2. Planning consent and CAR license issuance is required for the Dochfour Weir Upgrade works, prior to start of the Construction Phase of the Proposed Development. As part of the CAR licence application, an updated Flood Risk Assessment will be required for the Dochfour Weir Upgrade. The Flood Risk Assessment is to demonstrate no negative impact to flood receptors (either around Loch Ness or downstream in River Ness) either by way of magnitude or frequency of flood events compared to a baseline of the current behaviour of the Loch Ness catchment and taking account of existing CAR licenses, and considering a range of flood events up to and including a 1 in 200 + climate change event.
3. A framework agreement for the Water Management Board is to be established prior to start of the Operations Phase of the Proposed Development to the satisfaction of SEPA and THC. The Water Management Board is to include for potential flood alleviation measures, including coordinated pumping of the PSH schemes in the event of a flood warning.
4. The Dochfour Weir Upgrade construction is to be completed and in operation, with the Water Management Board or similar formed, prior to full energisation.

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Technical Note

Project name	Subject	Date
Glen Earrach PSH	Summer variable weir flood impact analysis	23/10/2025

Introduction

As part of the mitigations proposed for the Glen Earrach Pumped Storage Hydro (referred to as the Proposed Development) scheme, a variable weir at Ness Weir (referred to as the Dochfour Weir Upgrade by the Applicant) has been proposed as a Planning Condition for the Proposed Development. The variable weir would be operated in the summer season (April to September) as a mitigation measure. Further evidence has been requested of the impact of the variable weir in the event of a flood event occurring in the summer season. To address this, a range of flood event inflow hydrographs have been developed for 1 in 50 year (2% AEP), 1 in 100 year (1% AEP), and 1 in 200 year + climate change (0.5% AEP + 40%) and tested with a variable weir in a number of operational scenarios using a water balance model.

Both the Proposed Development alone and in combination with all existing and proposed Pumped Storage Hydro (PSH) schemes have been assessed (namely Foyers PSH, Loch na Cathrach PSH and Loch Kemp Storage).

Derivation of summer inflow hydrographs

Summer flood frequency analysis for River Ness at Ness-side

Review of the AMAX series for Ness-side indicates that 50 out of 52 of annual maximum flows occur between October and March. Review of the peaks over a threshold (POT) series reveals 22 out of 273 occur between April and September (Table 1). Of these, only one event exceeds QMED of 385 m^3/s. Flood events can therefore be said to be rare in the summer, and when they occur, they are more modest in scale.

It should be noted that the following method used to estimate the summer flood events is subject to some uncertainty as it has necessarily involved some non-standard application of the hydrological estimation methods. This is because the standard method is based on extreme value analysis of annual maximum flows, rather than maximum flows within a shorter seasonal period. This approach is nevertheless considered sufficiently representative for use to illustrate the behaviour of the scheme(s) and variable weir during the summer season.

A summer AMAX series was developed from the raw gauge data, by extracting the peak flow in each year occurring between April and September. This provided a summer QMED figure of 214 m^3/s.

The standard pooled analysis was not considered valid for this analysis (as the gauges in the pooling group have all-year AMAX data, rather than summer season only) so a single site statistical analysis was undertaken. It should be noted that with 72 years of data, this only provides a robust estimate up to about a 1 in 50 year event, so there is uncertainty in the extrapolation required to estimate the 200 year peak flow figure. The resulting summer flood frequency curve is shown in the Table 2.

Table 1: Ness-side POT events between April and September

Date	Flow (m3/s)
25/09/1975	275.3
27/07/1980	273.7
21/09/1981	252.3
19/09/1983	307.5
20/09/1989	257.7
24/09/1991	272.6
01/04/1994	364.4
27/04/1994	333.4
02/04/2008	233
21/09/2004	328.8
04/09/2009	259.2
06/04/2010	242.7
07/04/2011	392
24/05/2011	240.4
17/07/2011	269.8
11/08/2011	289.8
14/05/2012	266.5
17/04/2013	232.2
12/08/2014	246.5
20/09/2018	315.6
01/09/2019	311
14/09/2020	269

Table 2: Ness-side summer flood frequency curve

Return period (years)	AEP%	Peak flow m^3/s
2	50%	214
5	20%	266
10	10%	302
20	5%	338
25	4%	349
30	3%	359
50	2%	388
75	1.33%	412
100	1%	430
200	0.5%	475
200+CC		665

These are the peak flows estimated for Ness-side, essentially the outflow from Loch Ness. In order to undertake the analysis required, an *inflow* hydrograph to Loch Ness is required.

Summer inflow hydrograph

The statistical analysis method above only provides a peak flow estimate, not a full flood hydrograph. The catchment draining to Loch Ness is heavily modified by man-made influences, in particular hydro power infrastructure and operation. As such, standard hydrological methods to estimate flood hydrographs which are based on essentially unmodified rural catchments, are unlikely to provide a representative hydrograph shape of the catchment inflow to Loch Ness.

Foyers level data is available from 2014. This data was used along with the rating curve for Ness weir and flow data from the downstream gauge on the River Ness at Ness-side to derive an inflow record for the period from 2014 (this is described in Volume 5, Appendix 11.1 of the EIA). This means that we have modelled inflow hydrographs for flood events that have occurred since 2014 on which to base the hydrograph shape for the return period events.
In order to identify a suitable hydrograph at Ness-side on which to base the summer 200 year + CC hydrograph shape, several events were plotted, shown below.

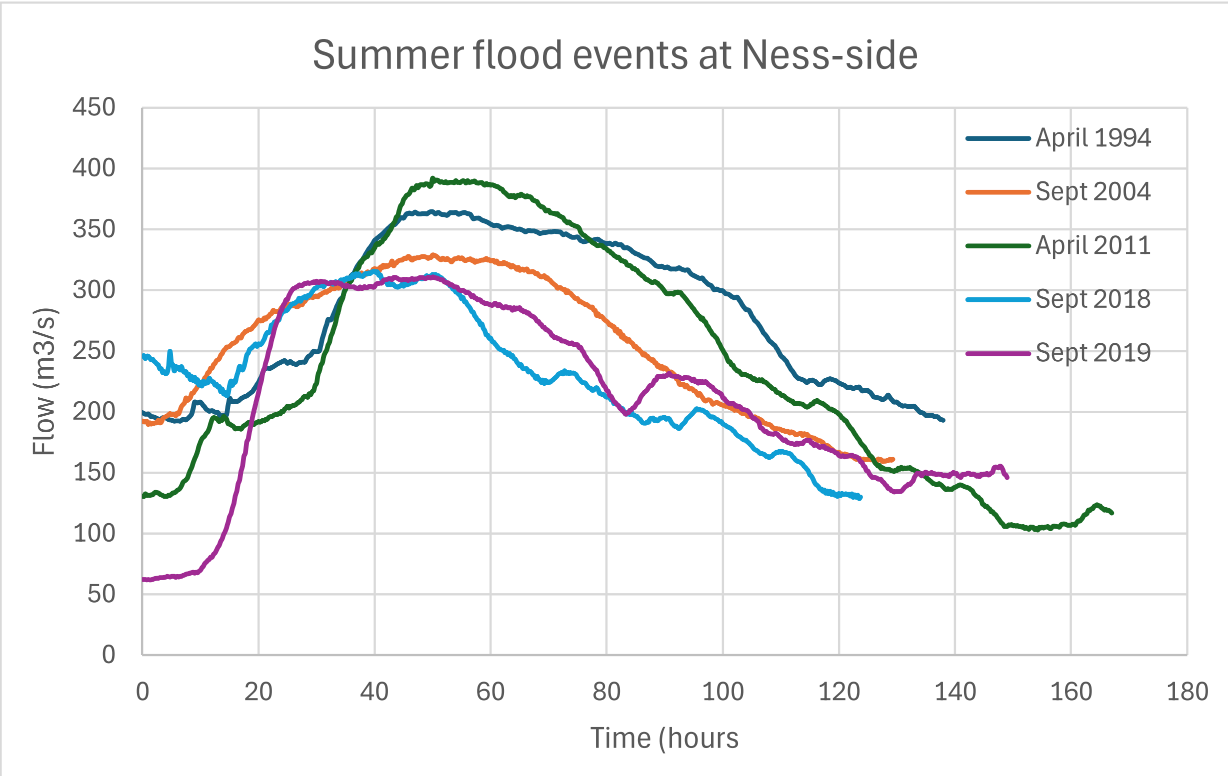


Figure 1: Summer flood events on River Ness at Ness-side

Although not the highest recorded flow, it can be seen that the September 2019 event has the longest duration and the steepest increase in flow on the rising limb of the hydrograph. These characteristics would provide a more severe test so this hydrograph shape was selected. As this event is within the modelled period of record, we have the estimated inflow hydrograph and this has been scaled up by the ratio of peak flows of return period to Sept 2019. A further scaling factor was introduced to correct for increased attenuation for the larger events, to ensure the baseline outflow from the modelling matched the peak flow estimates for Ness-side. The final hydrographs are shown in the figure below.

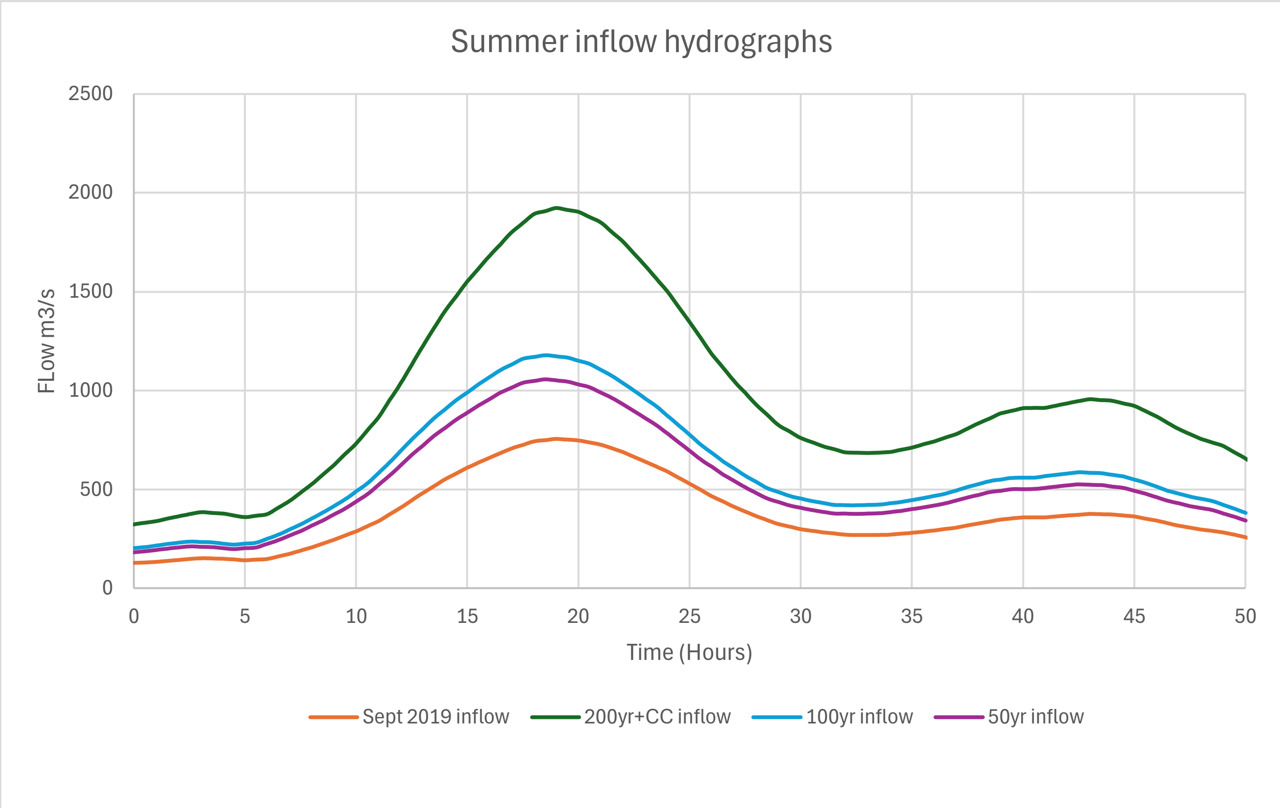
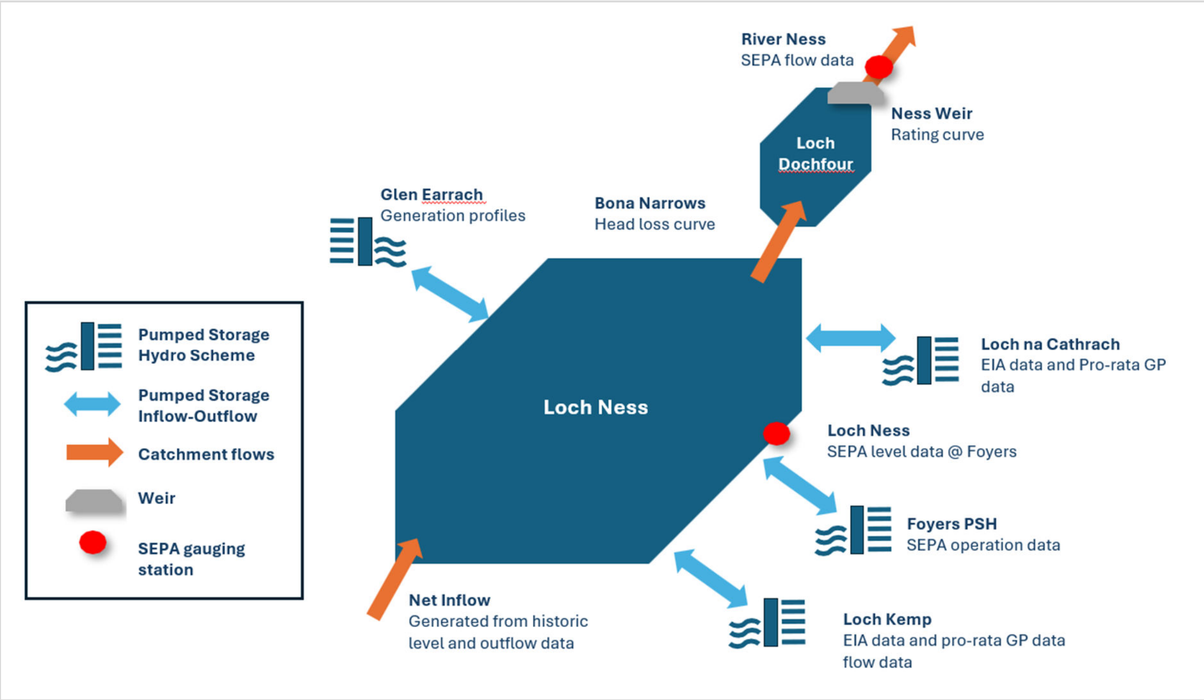


Figure 2: Summer inflow hydrographs

Modelling the impact of the variable weir during a summer flood

Water balance model

The modelling to assess the impact of the Proposed Development (with and without the other existing and proposed PSH schemes in operation) on flood risk has used a water balance approach. This essentially balances the inflow, outflow and change in loch storage for each time step of the simulation and is fully described in Volume 5, Appendix 11.1 of the EIA.



Variable weir modelling

The water balance model has been used to assess the impact of a summer flood event with the variable weir in operation for the case of the Proposed Development alone, and for all existing and proposed PSH schemes.

The following assumptions are made in the modelling:

1. Peak downstream flows in River Ness should not increase above baseline peak flows;
2. Maximum variable weir level is taken to be +0.5m (16.23mAOD), corresponding to the maximum raised level associated with the Proposed Development's operation when assessing the Proposed Development alone, and +1.23m (16.96mAOD) when assessing all schemes. Agreement of these maximum weir levels would form part of the detailed application and design of the Dochfour Weir proposal;
3. At the start of each simulation the weir is raised to its maximum level. Implicit in this assumption is that all schemes have previously undertaken a full generating cycle (i.e. full head pond storage has been discharged into Loch Ness) and completes as the rising limb of the flood event begins. This assumption minimises the available response time and is therefore conservative. The generation model is based on assessment of market conditions and the in general generation cycle duration will be between 1 and 3 hours with occasional longer duration generation cycles. A full cycle of generation is therefore a very conservative assumption;
4. Weir lowering rate is 0.2m per hour except where limited by assumption 1. This means that it may be necessary to raise the weir after dropping in order to limit downstream flows; and
5. Initial loch levels are based on the mean loch level in the summer taken from the level duration analysis (see Volume 5, Appendix 11.1 of the EIA).

Some extended analysis has looked at the impact of introducing pumping back to the head pond under various triggers as well as controlling the level of the variable weir in order to showcase the potential betterment afforded by the variable weir coupled with the additional storage provided by the head pond:

1. At a level of 16.9mAOD, pumping back to the headpond is initiated and continues until the headpond is full. At this level all schemes start to pump back into the head ponds. Pumping continues until the head ponds are full or the level drops below 16.9mAOD. Pumping capacities of 33%, 50% and 67% have been tested to model robust levels of redundancy with respect to available pumping capacity in the event of a flood event; and
2. Pumping at the start of the flood until the head pond is full.

The Proposed Development scheme, 0.5m variable weir

Summer 200 year + climate change results

At the 200 year + CC event, the modelled baseline peak level is 17.43mAOD with a corresponding peak outflow of 665m^3/s. Controlling the weir level to maintain the same outflow results in an increase in loch level to 17.67mAOD, an increase of 240mm (Figures 3 and 4). Inclusion of pumping at 33% of capacity from the start of the flood shows betterment in terms of both a lower peak loch level and lower downstream peak flow (Figures 5 & 6).

Table 3: Variable weir, Proposed Development only, Summer 200 year + CC event

	Baseline	Weir control only	Weir control and pump @16.9mAOD (33% pump capacity)	Weir control and pump @16.9mAOD (50% pump capacity)	Weir control and pump from start of flood (33% pump capacity)
Max level (mAOD)	17.43	17.67	17.44	17.35	17.38
Max outflow (m^3/s)	665	665	665	638	650

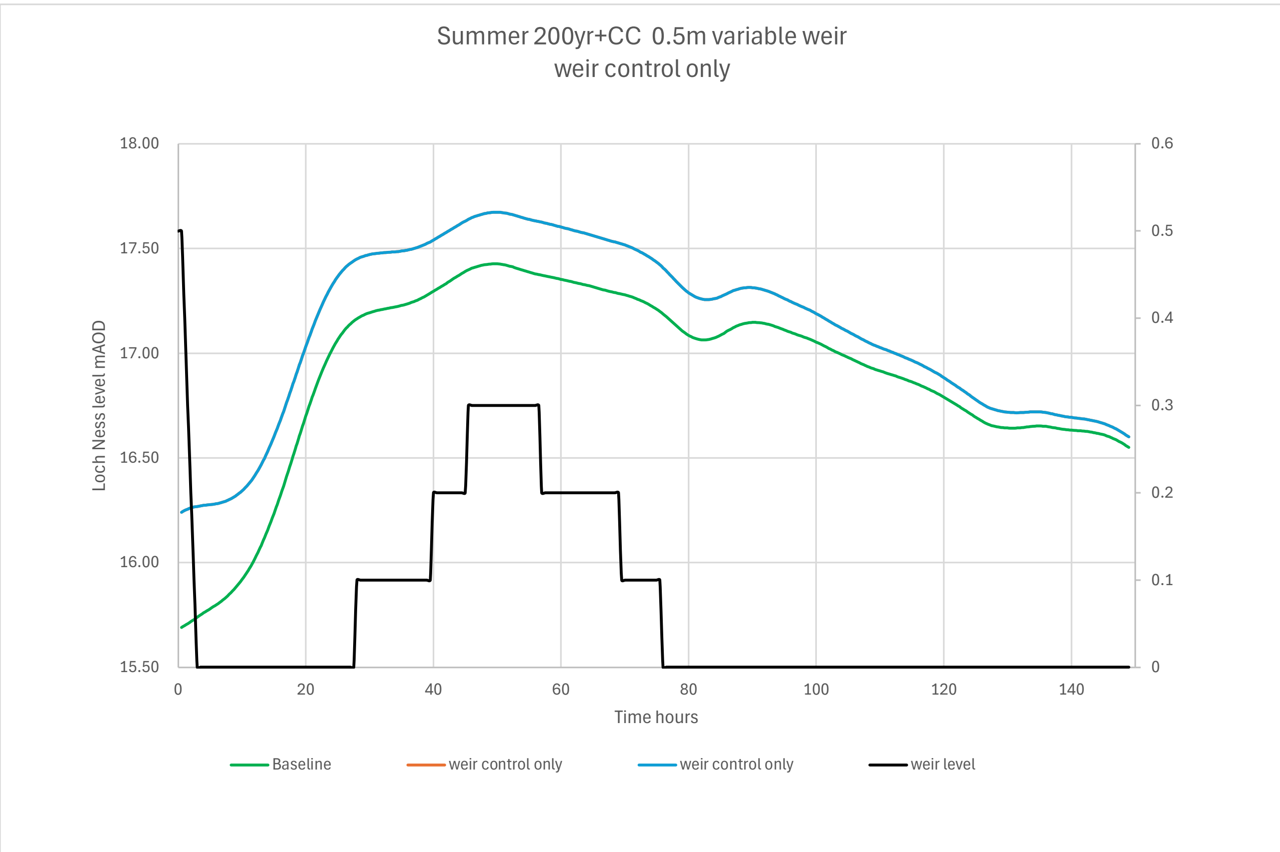


Figure 3: Summer 200yr+CC, 0.5m variable weir, weir control only – level

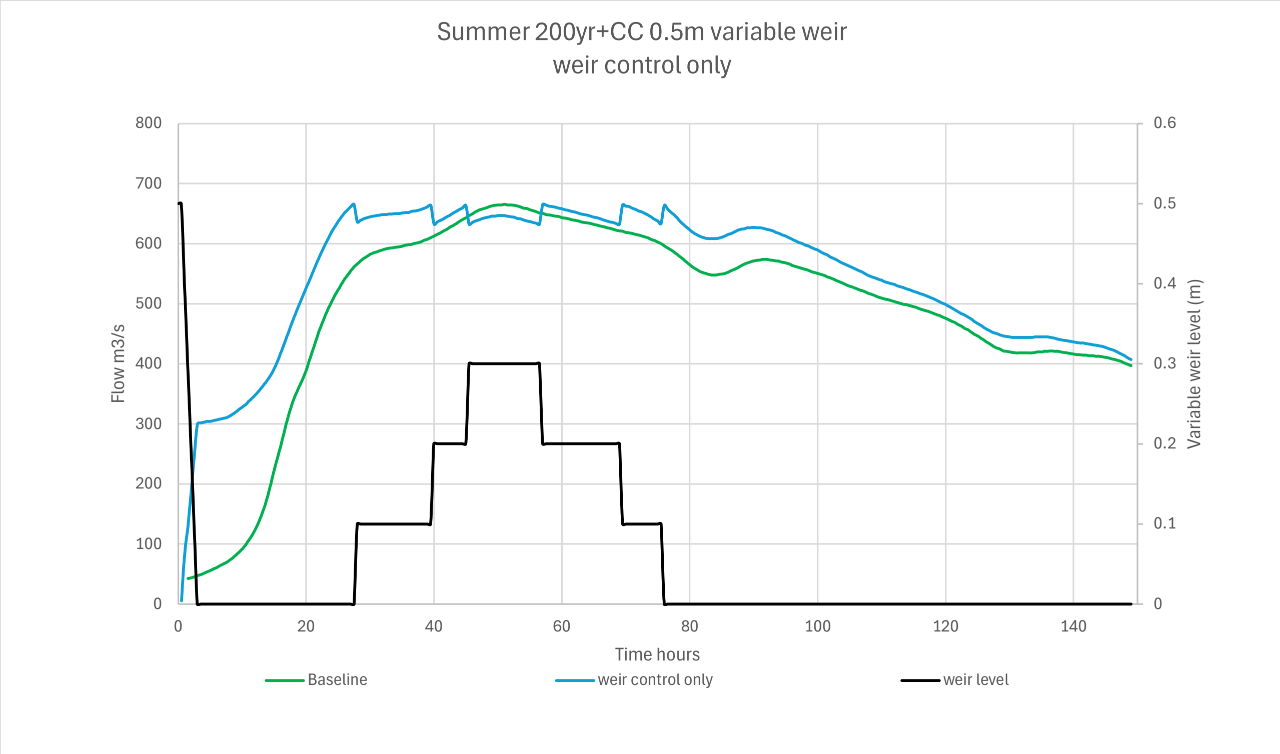


Figure 4: Summer 200yr+CC, 0.5m variable weir, weir control only – flow

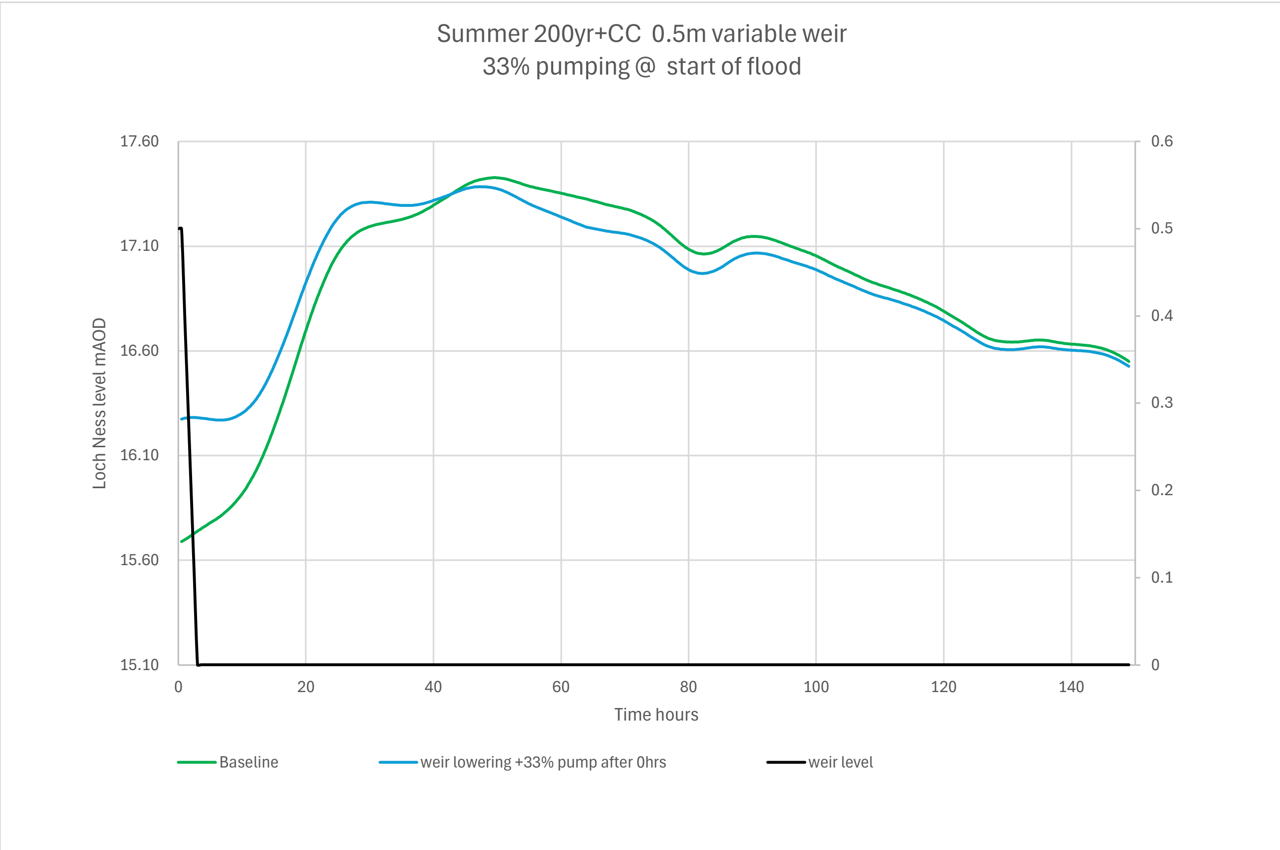


Figure 5: Summer 200yr+CC, 0.5m variable weir, 33% pumping at start of flood – level

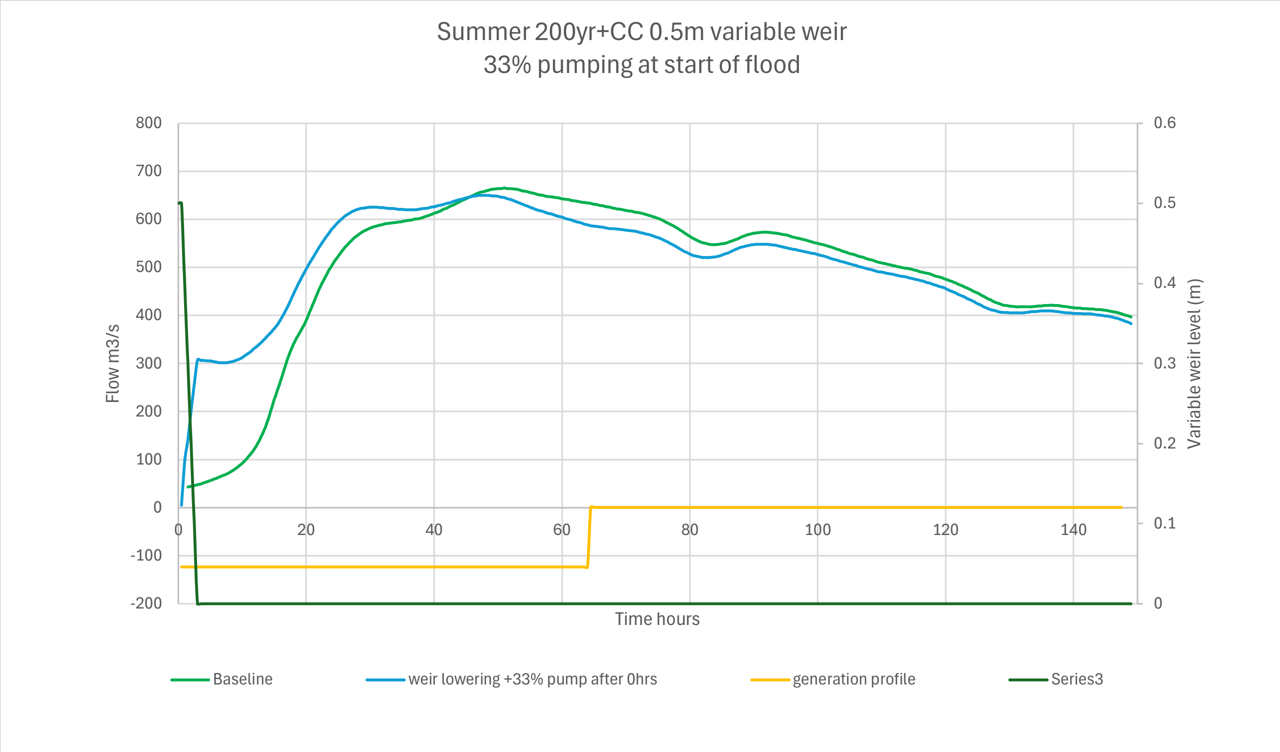


Figure 6: Summer 200yr+CC, 0.5m variable weir, 33% pumping at start of flood – flow

Summer 100 year results

The table below shows the modelling results for the summer 100 year event. Using the weir to control the downstream flow to match the baseline case results in a peak loch level of 16.96mAOD compared to a baseline peak loch level of 16.68mAOD, an increase of 280mm (Figures 7 and 8). Inclusion of 50% pumping capacity at the start of the flood provides betterment, lowering both the peak loch level and peak downstream flows (Figures 9 and 10).

Table 4: Variable weir, Proposed Development only, Summer 100yr event

	Baseline	Weir control only	Weir control and pump from start of flood (33% pump capacity)	Weir control and pump from start of flood (50% pump capacity)
Max level (mAOD)	16.68	16.96	16.69	16.60
Max outflow (m^3/s)	430	430	430	404

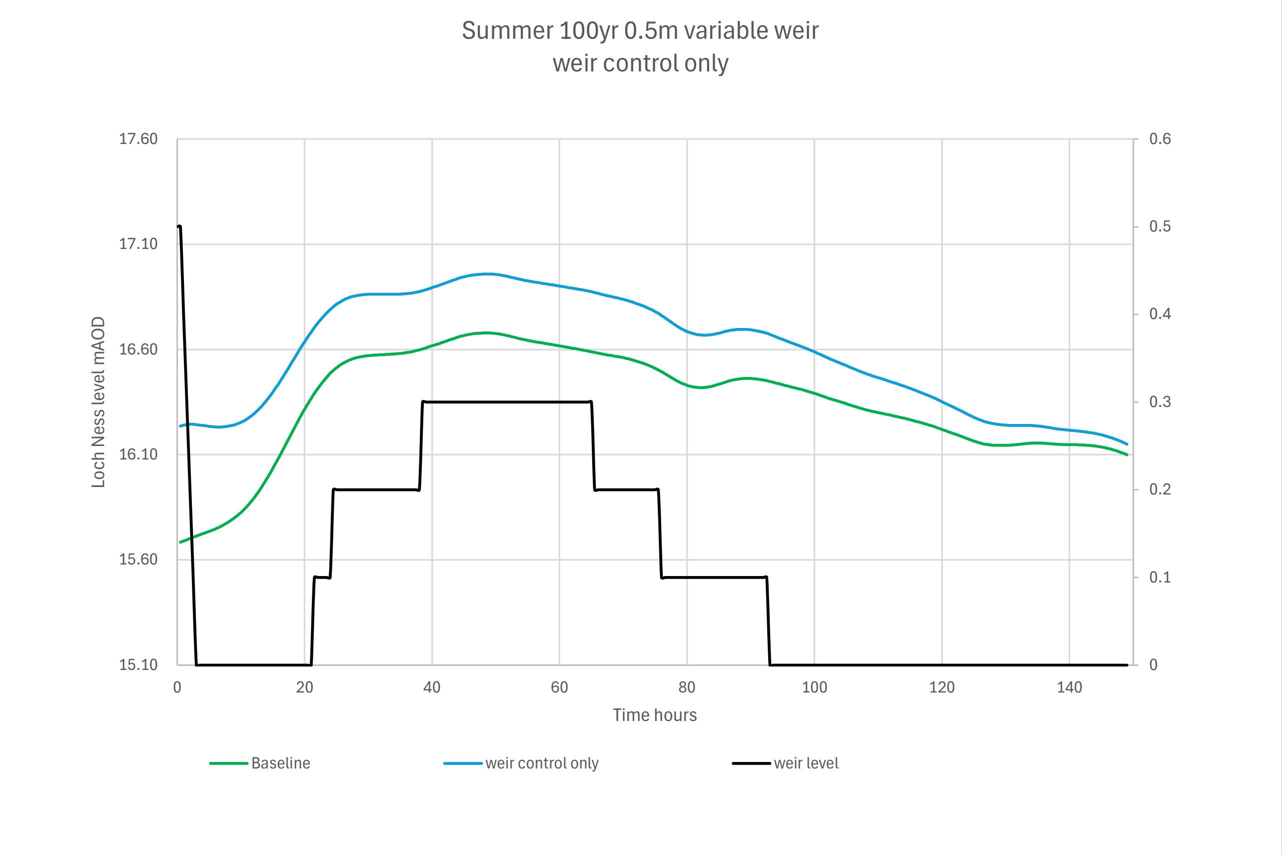


Figure 7: Summer 100yr, 0.5m variable weir, weir control only – level

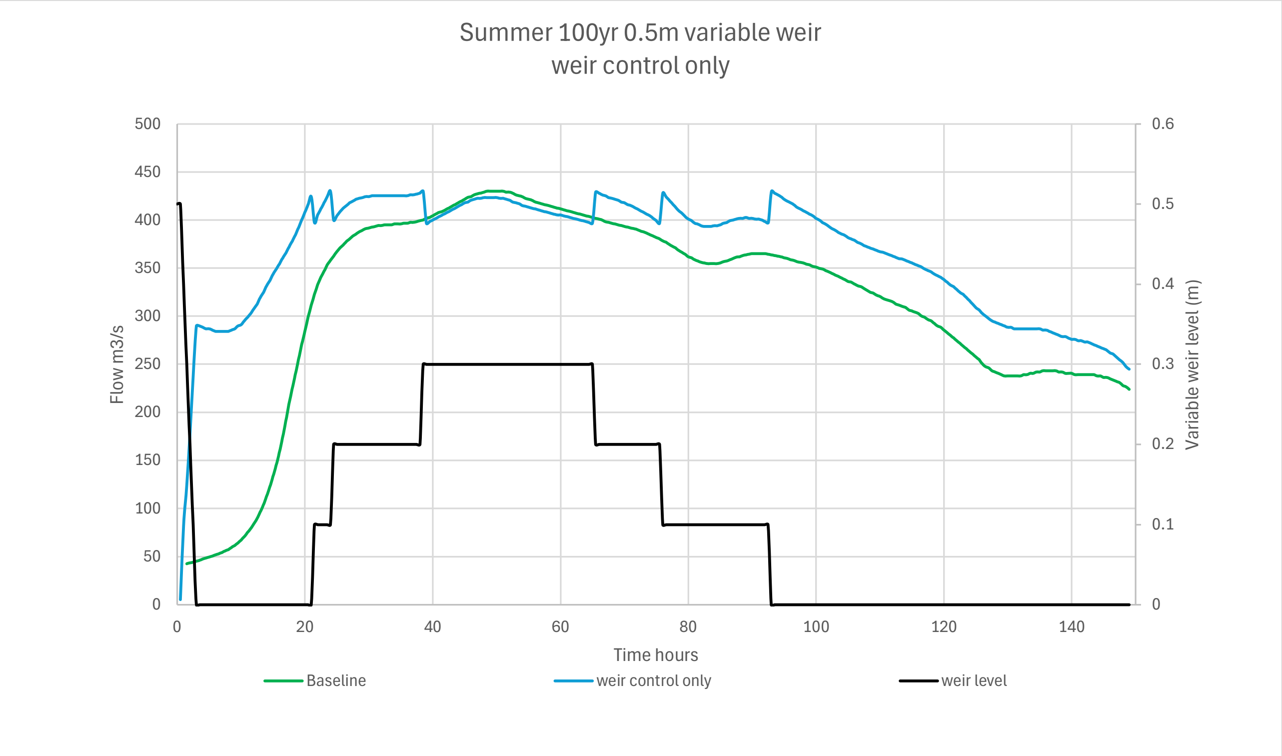


Figure 8: Summer 100yr, 0.5m variable weir, weir control only – flow

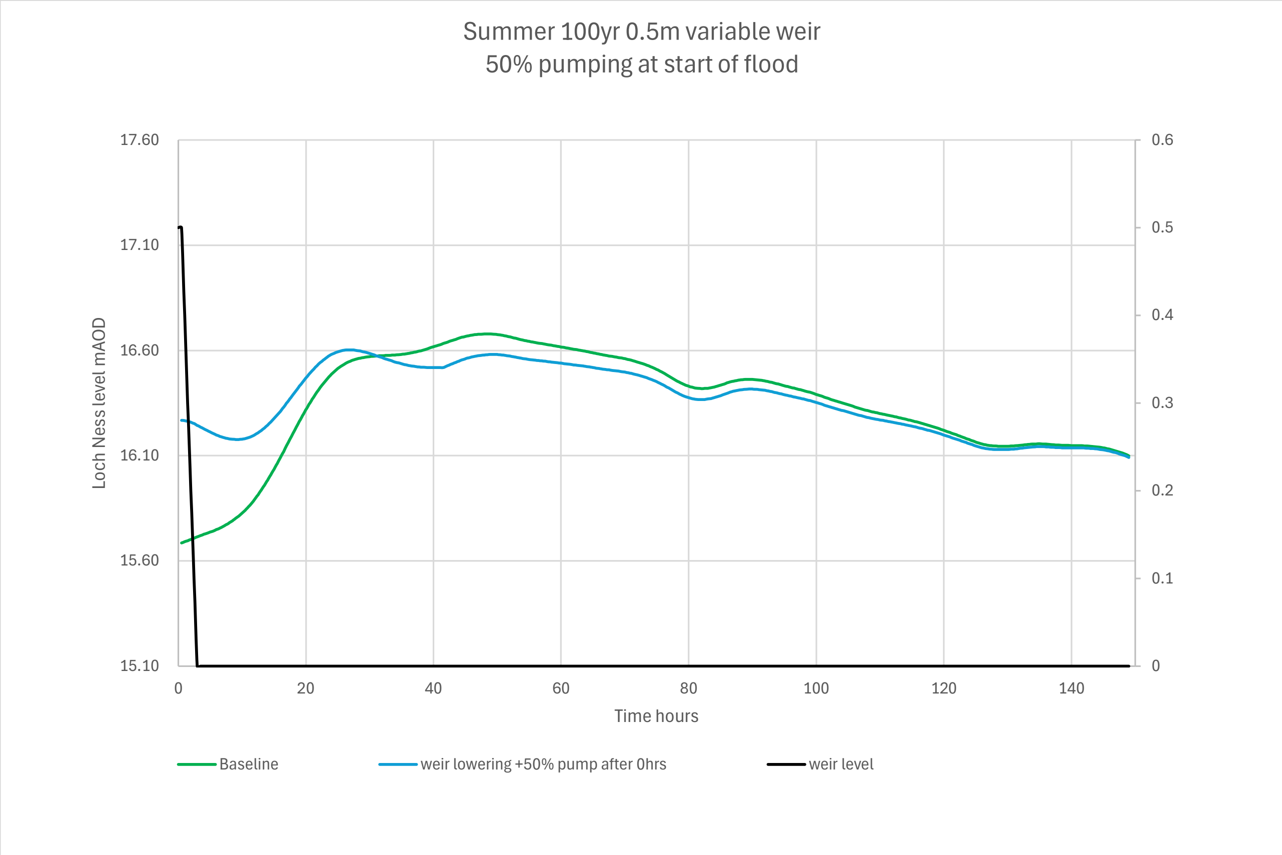


Figure 9: Summer 100yr, 0.5m variable weir, 50% pumping at start of flood – level

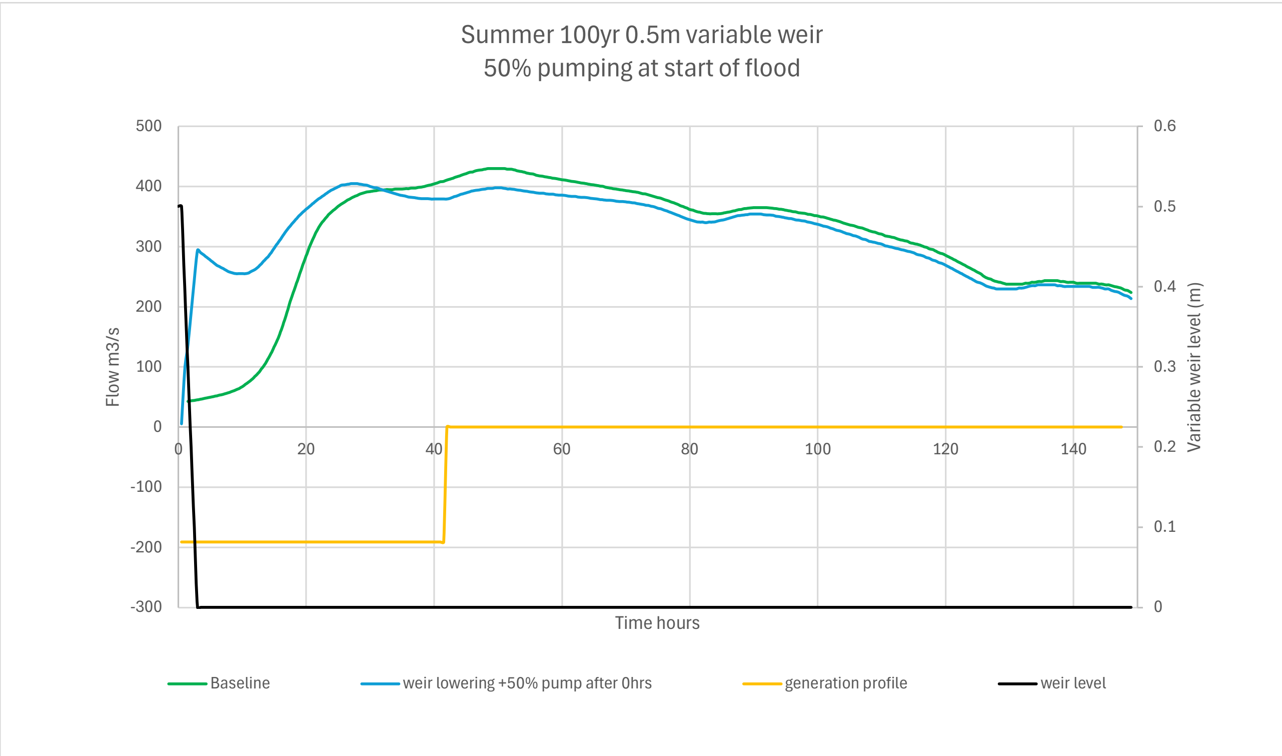


Figure 10: Summer 100yr, 0.5m variable weir, 50% pumping at start of flood – flow

Summer 50 year results

The table below shows the modelling results for the summer 50 year event. Using the weir to control the downstream flow to match the baseline case results in a peak loch level of 16.86mAOD compared to the baseline peak loch level of 16.56mAOD, an increase of 200mm (Figures 11 and 12). Inclusion of 50% pumping capacity at the start of the flood again provides betterment, lowering both the peak loch level and peak downstream flows (Figures 13 and 14).

Table 5: Variable weir, Proposed Development only, Summer 50yr event

	Baseline	Weir control only	Weir control and pump from start of flood (33% pump capacity)	Weir control and pump from start of flood (50% pump capacity)
Max level (mAOD)	16.56	16.86	16.60	16.50
Max outflow (m^3/s)	388	388	388	376

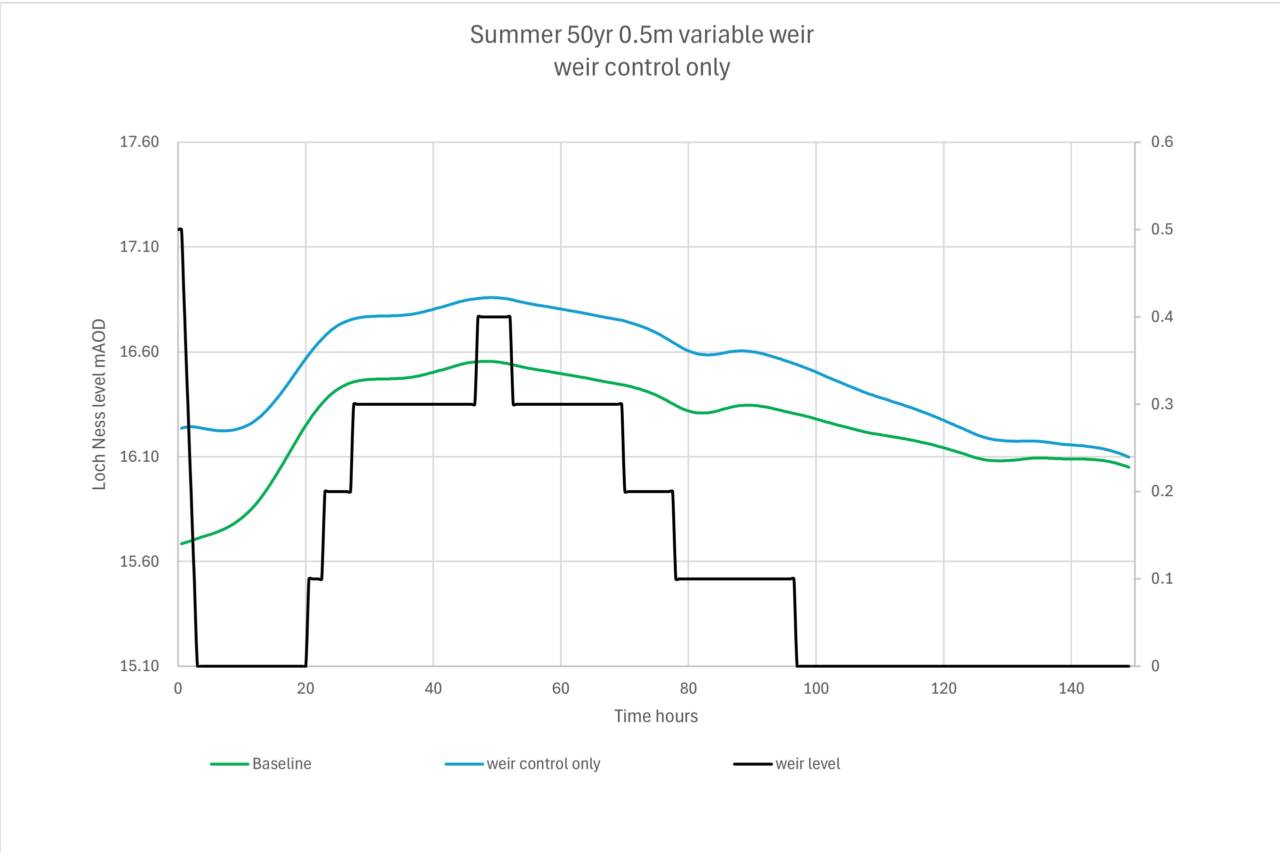


Figure 11: Summer 50yr, 0.5m variable weir, weir control only – level

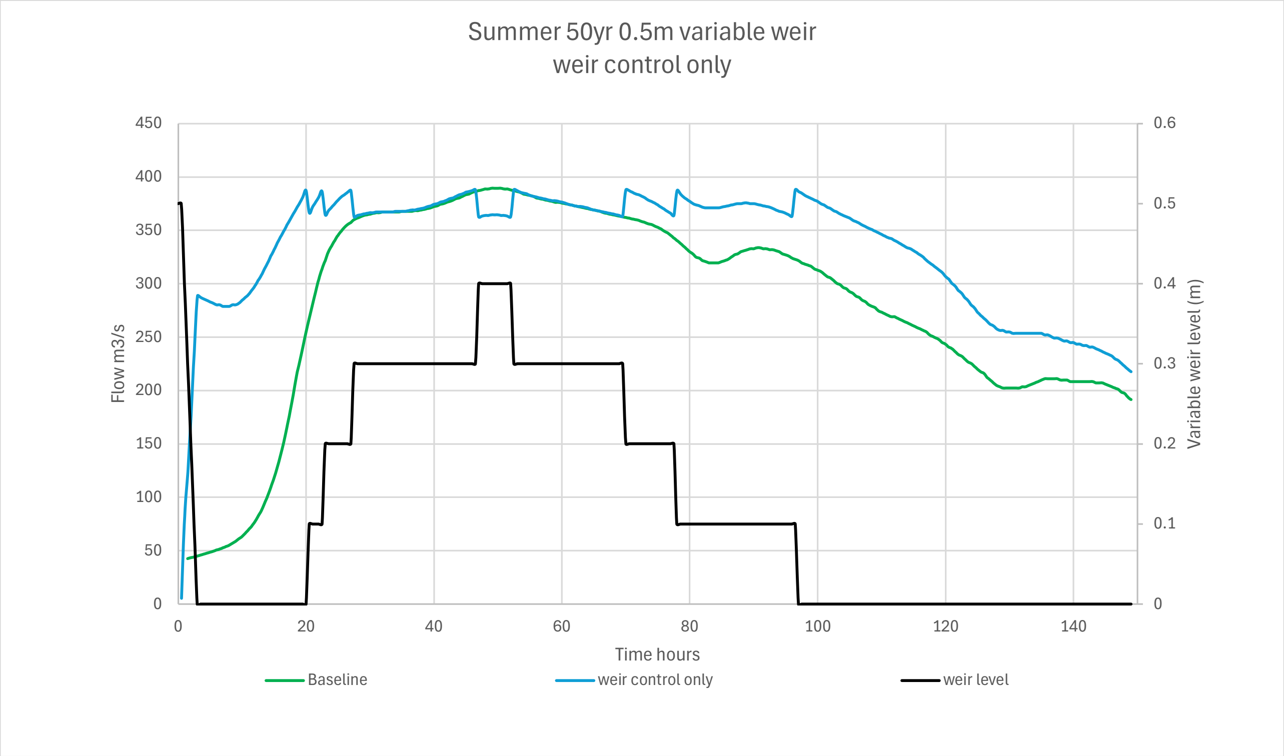


Figure 12: Summer 50yr, 0.5m variable weir, weir control only – flow

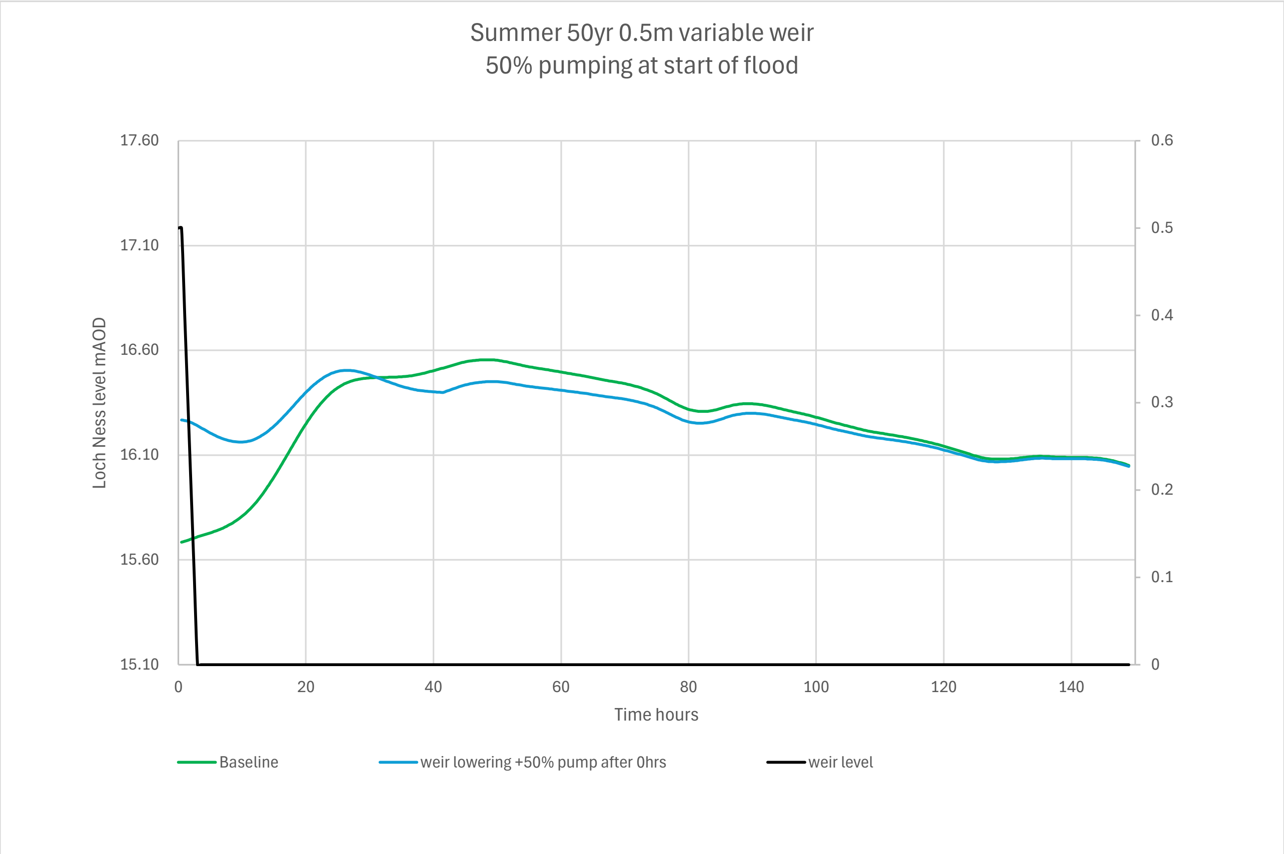


Figure 13: Summer 50yr, 0.5m variable weir, 50% pumping at start of flood – level

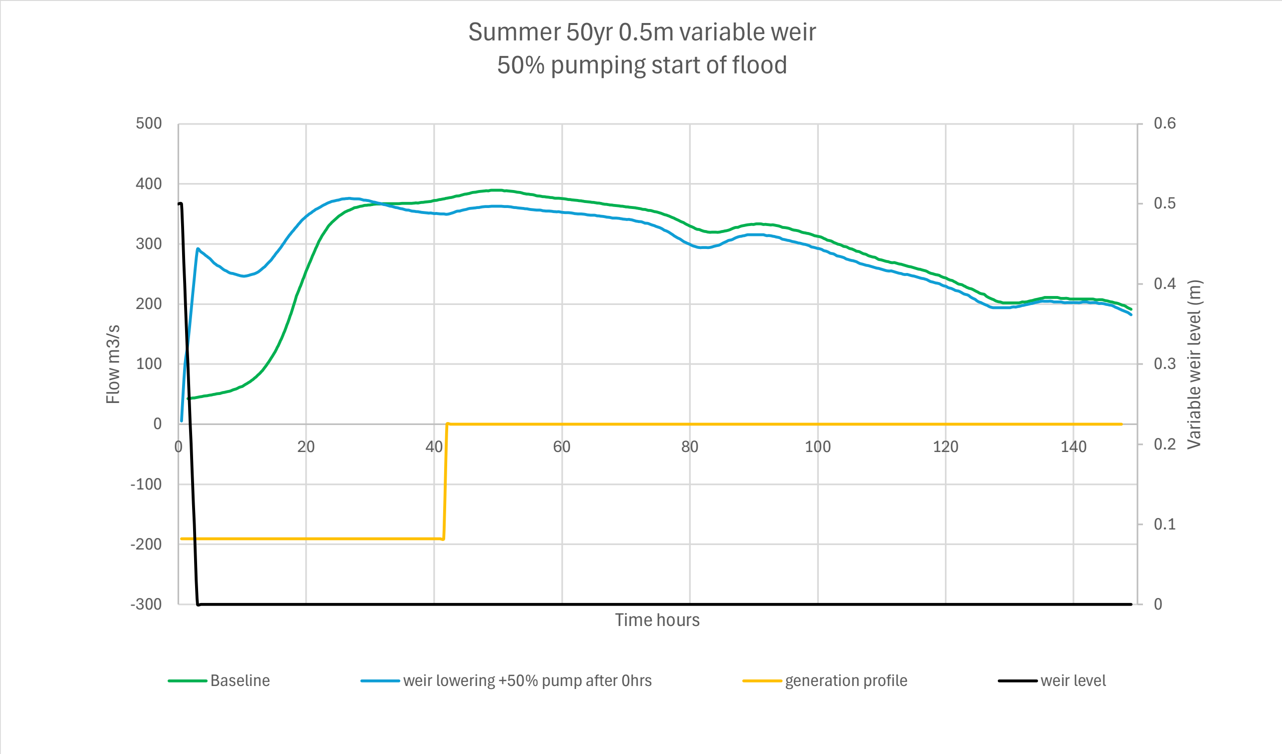


Figure 14: Summer 50yr, 0.5m variable weir, 50% pumping at start of flood – flow

All PSH schemes, 1.23m variable weir

Summer 200 year + climate change results

The table below shows the modelling results for the summer 200 year + climate change event. Using the weir to control the downstream flow to match the baseline case results in a peak loch level of 17.52mAOD compared to a baseline peak loch level of 17.43mAOD, an increase of 90mm (Figures 15 and 16). The reason that this peak level is lower than the Proposed Development only case is because of the ability to drop the weir by 1.23m rather than 0.5m at the start of event, meaning that a greater volume can be discharged before the peak.

Inclusion of 50% pumping capacity at the start of the flood again provides betterment, lowering both the peak loch level and peak downstream flows (Figures 17 and 18).

Table 6: Variable weir, all schemes, Summer 200 year + CC event

	Baseline	Weir control only	Weir control and pump from start of flood (33% pump capacity)	Weir control and pump from start of flood (50% pump capacity)
Max level (mAOD)	17.43	17.52	17.41	17.26
Max outflow (m^3/s)	665	663	658	608

Figure 15: Summer 200yr+CC, 1.23m variable weir, weir control only – level

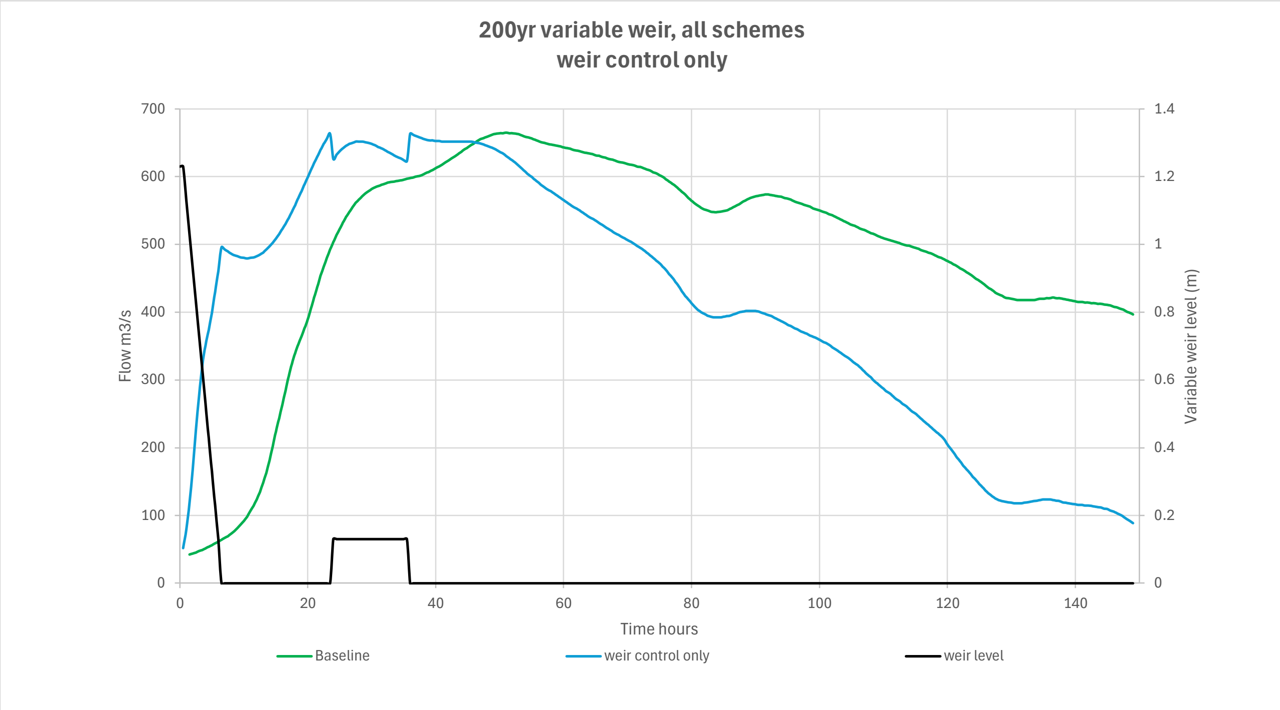


Figure 16: Summer 200yr+CC, 1.23m variable weir, weir control only – flow

Figure 17: Summer 200yr+CC, 1.23m variable weir, 50% pumping at start of flood – level

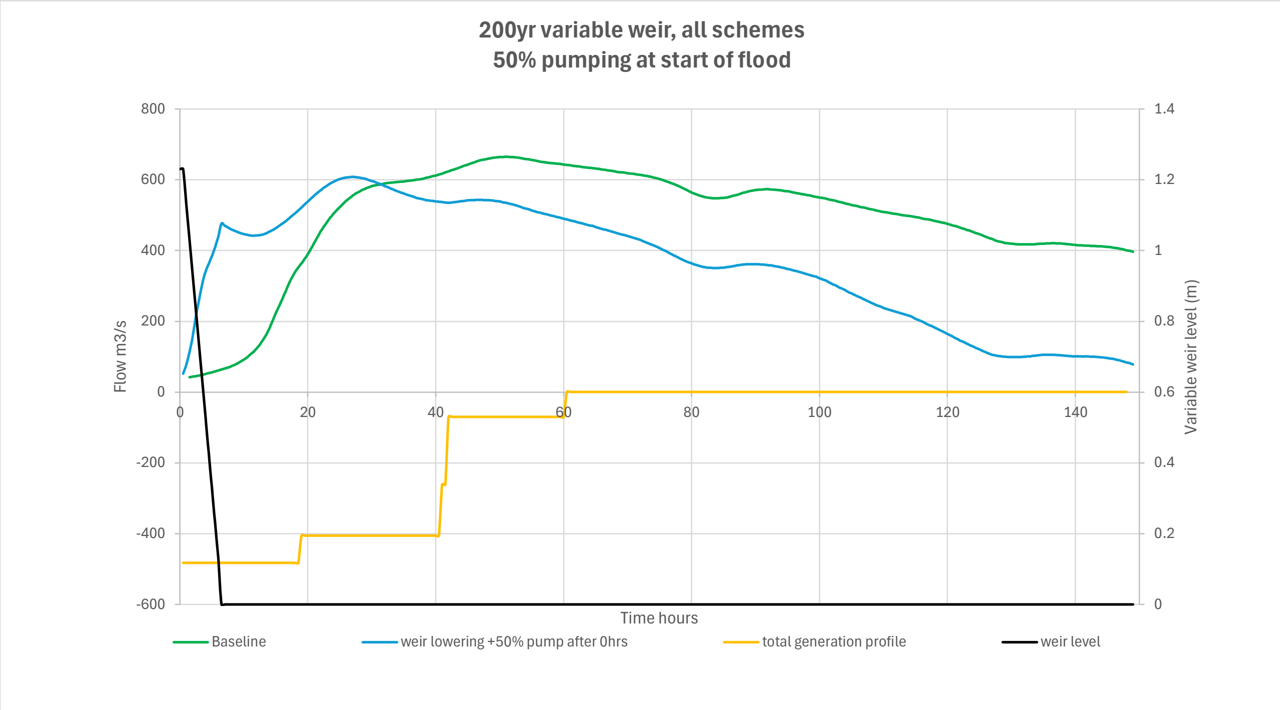


Figure 18: Summer 200yr+CC, 1.23m variable weir, 50% pumping at start of flood – flow

Summer 100 year results

The table below shows the modelling results for the summer 100 year event. Using the weir to control the downstream flow to match the baseline case results in a peak loch level of 16.99mAOD compared to a baseline peak loch level of 16.68mAOD, an increase of 310mm (Figures 19 and 20). For the other scenarios modelled, peak water levels remain below the initial level of 16.96mAOD. The maximum levels quoted in the table represent the highest levels reached following the initial drop in levels as the weir is lowered. Inclusion of 67% pumping capacity at the start of the flood provides betterment, lowering both the peak loch level and peak downstream flows (Figures 21 and 22).

Table 7: Variable weir, all schemes, Summer 100yr event

	Baseline	Weir control only	Weir control and pump from start of flood (33% pump capacity)	Weir control and pump from start of flood (50% pump capacity)	Weir control and pump from start of flood (67% pump capacity)
Max level (mAOD)	16.68	16.99	16.88*	16.73*	16.51*
Max outflow (m^3/s)	430	430	430	430	424

*Excluding starting level of 16.96mAOD

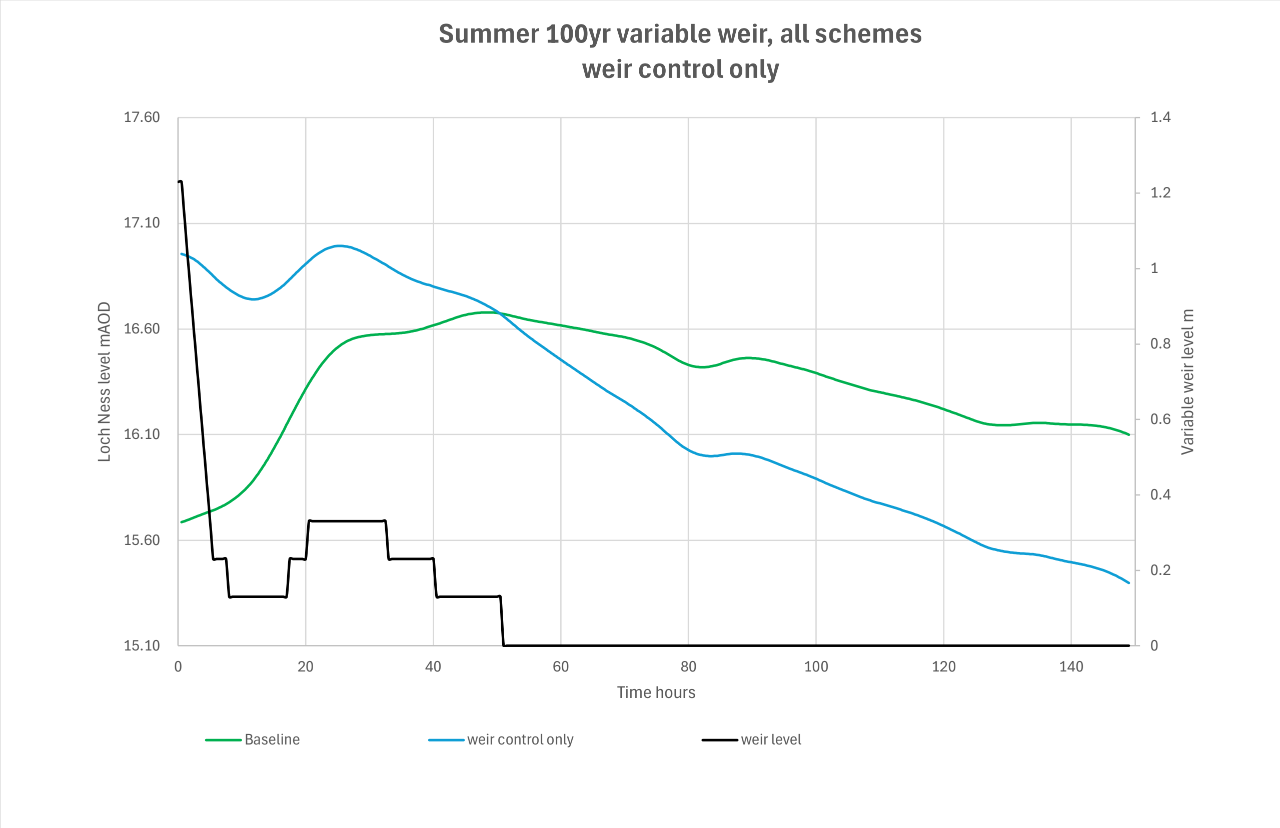


Figure 19: Summer 100yr, 1.23m variable weir, weir control only – level

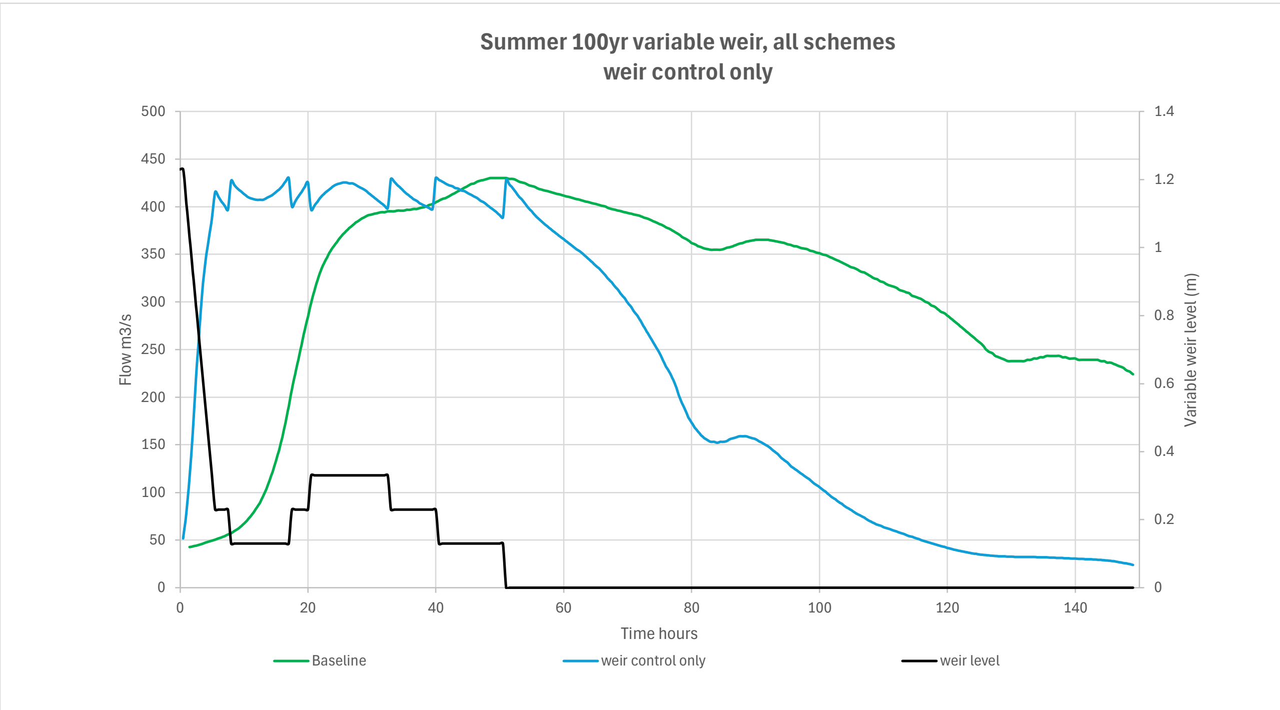


Figure 20: Summer 100yr, 1.23m variable weir, weir control only – flow

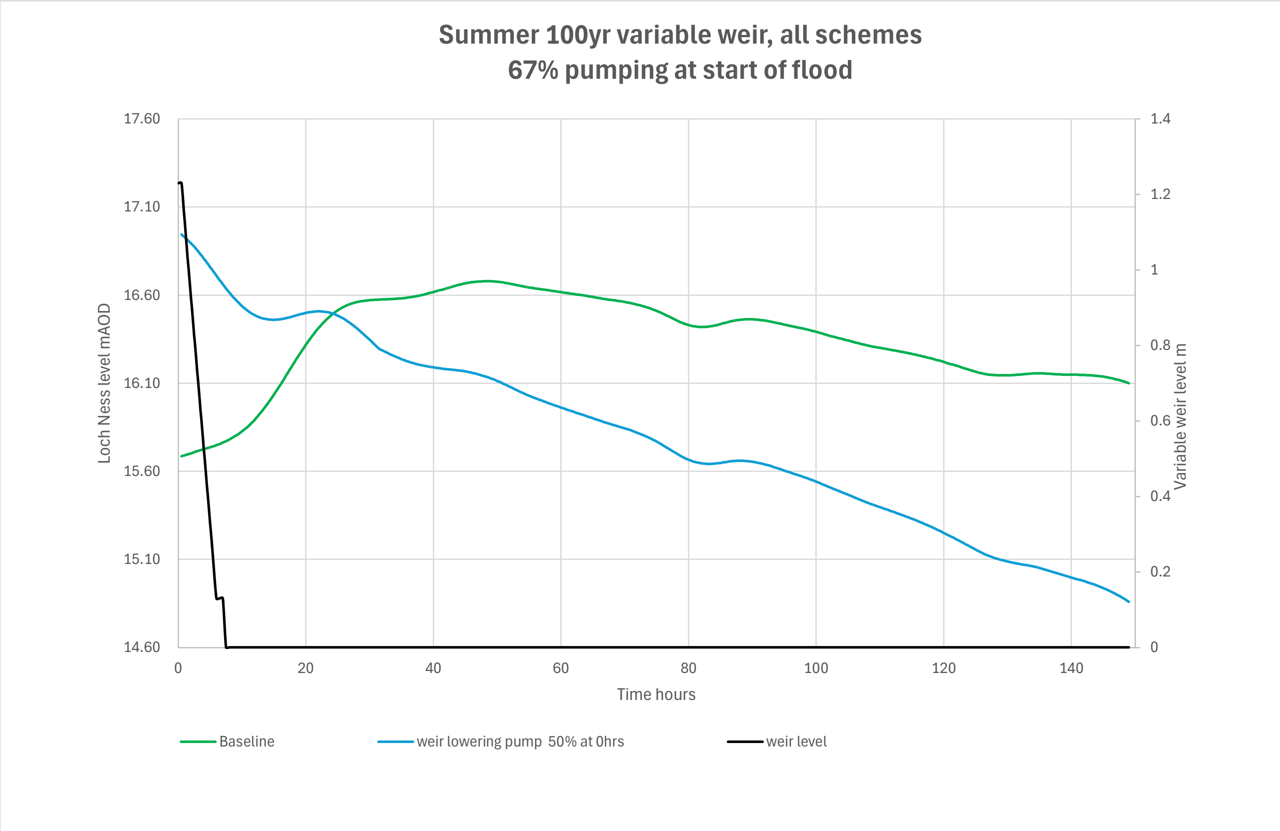


Figure 21: Summer 100yr, 1.23m variable weir, 67% pumping at start of flood – level

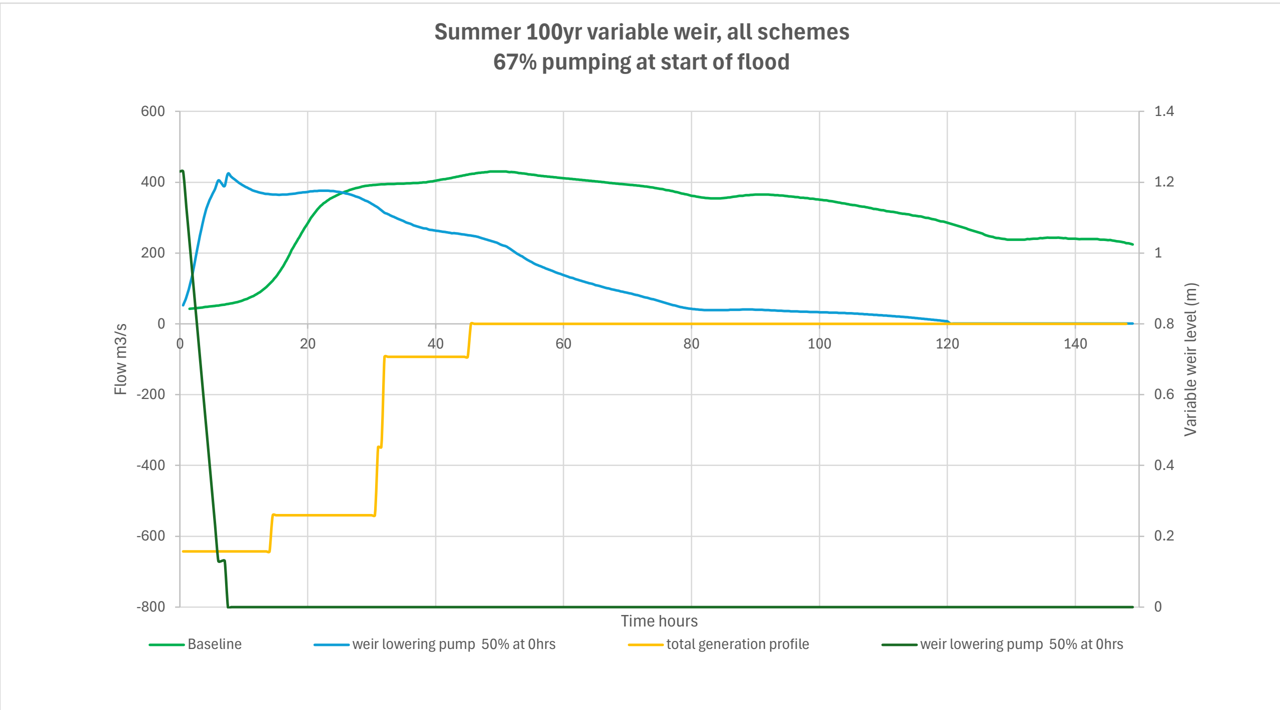


Figure 22: Summer 100yr, 1.23m variable weir, 67% pumping at start of flood – flow

Summer 50 year results

The table below shows the modelling results for the summer 50 year event. Using the weir to control the downstream flow to match the baseline case results in a peak loch level of 16.93mAOD compared to a baseline peak loch level of 16.56mAOD, an increase of 370mm (Figures 23 and 24). For all the scenarios modelled, peak water levels remain below the initial level of 16.96mAOD. The maximum levels quoted in the table represent the highest levels reached following the initial drop in levels as the weir is lowered. Inclusion of 67% pumping capacity at the start of the flood can provide betterment, lowering both the peak loch level and peak downstream flows (Figures 25 and 26).

Table 8: Variable weir, all schemes, Summer 50yr event

	Baseline	Weir control only	Weir control and pump from start of flood (33% pump capacity)	Weir control and pump from start of flood (50% pump capacity)	Weir control and pump from start of flood (67% pump capacity)
Max level (mAOD)	16.56	16.93*	16.81	16.65	16.44
Max outflow (m^3/s)	388	388	388	388	387

*Excluding starting level of 16.96mAOD

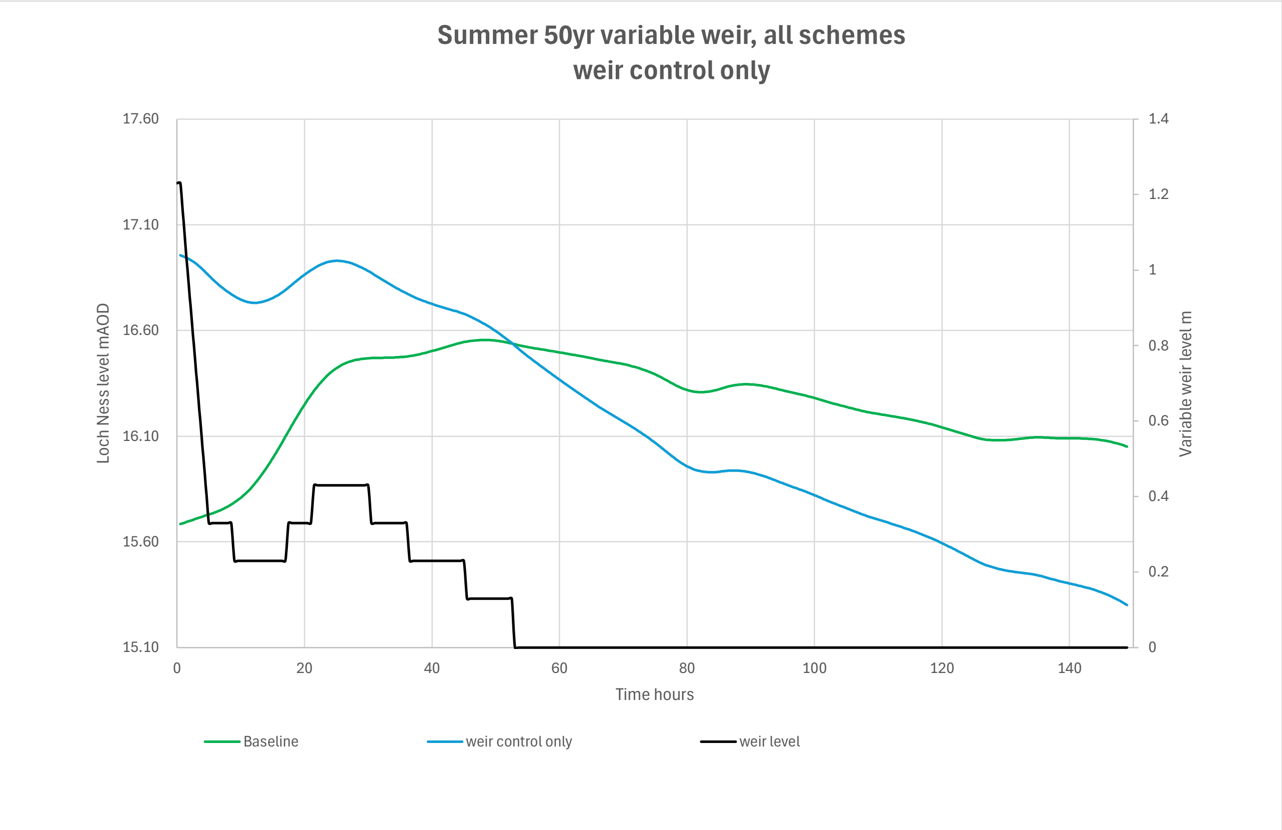


Figure 23: Summer 50yr, 1.23m variable weir, weir control only – level

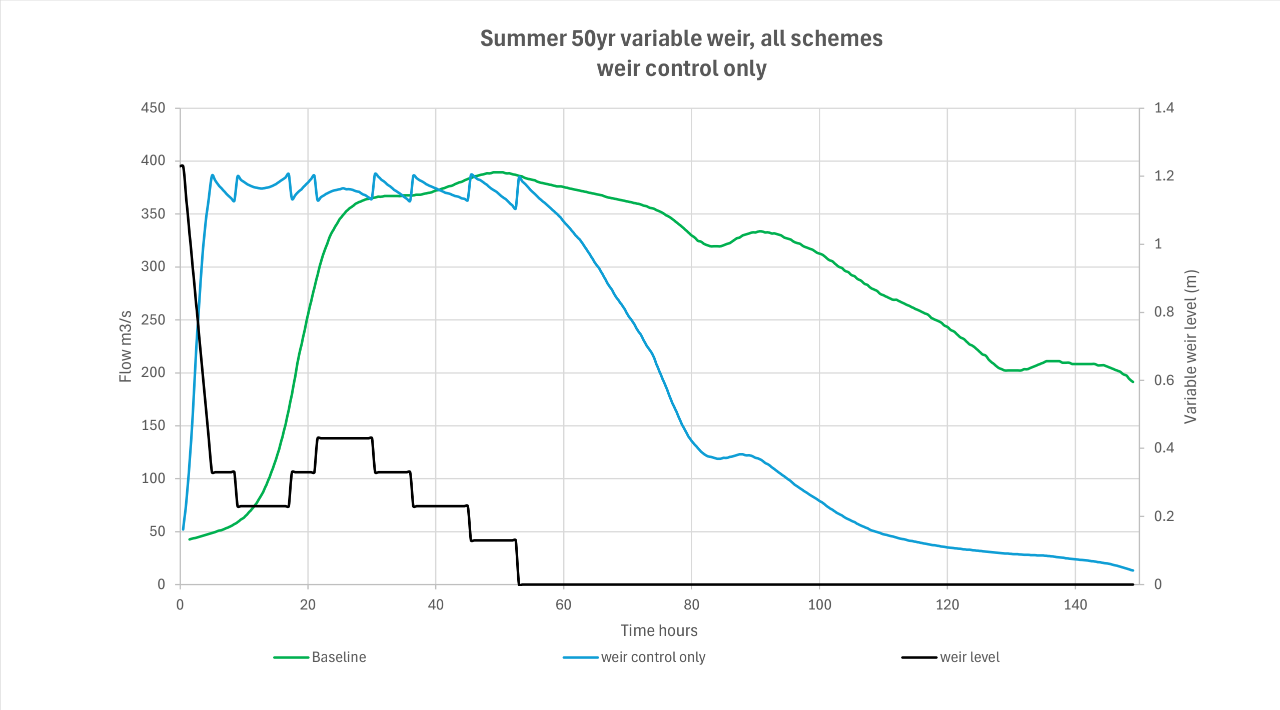


Figure 24: Summer 50yr, 1.23m variable weir, weir control only – flow

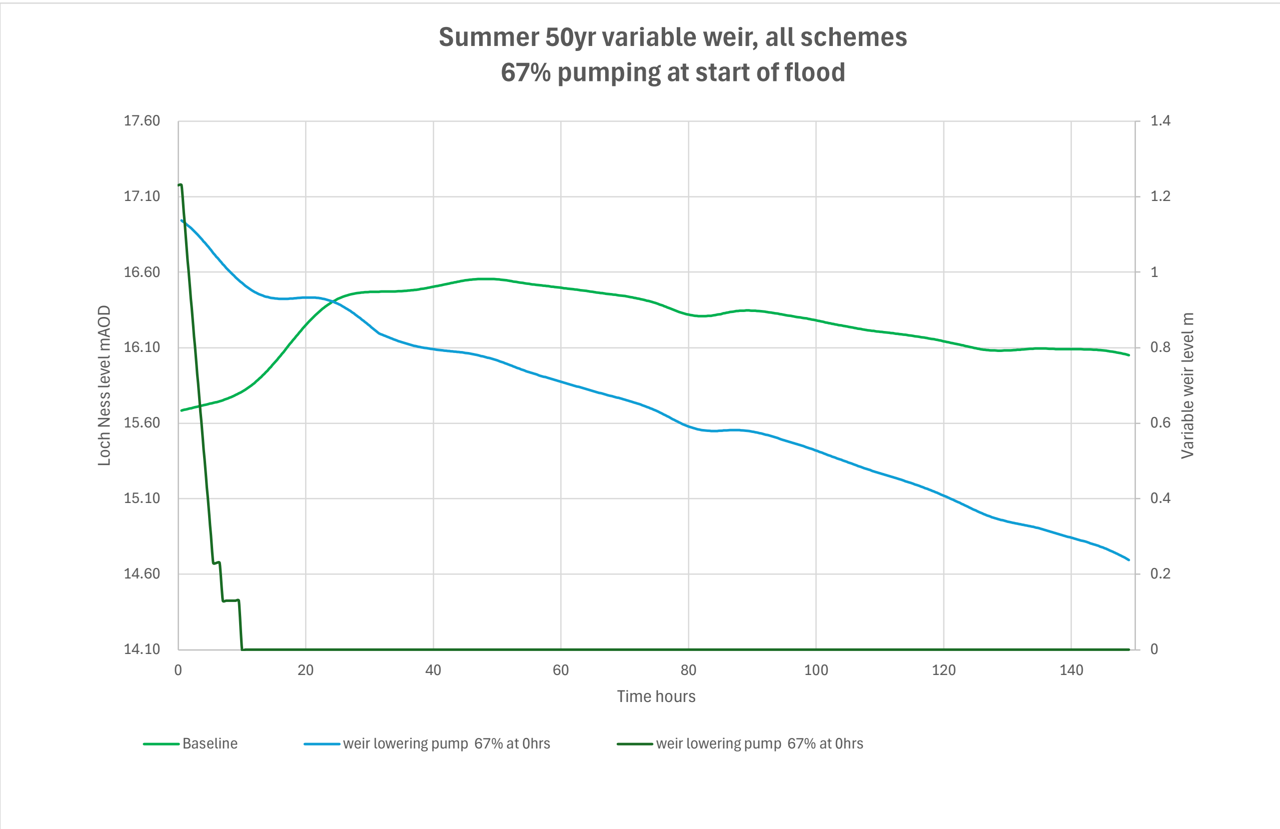


Figure 25: Summer 50yr, 1.23m variable weir, 67% pumping at start of flood – level

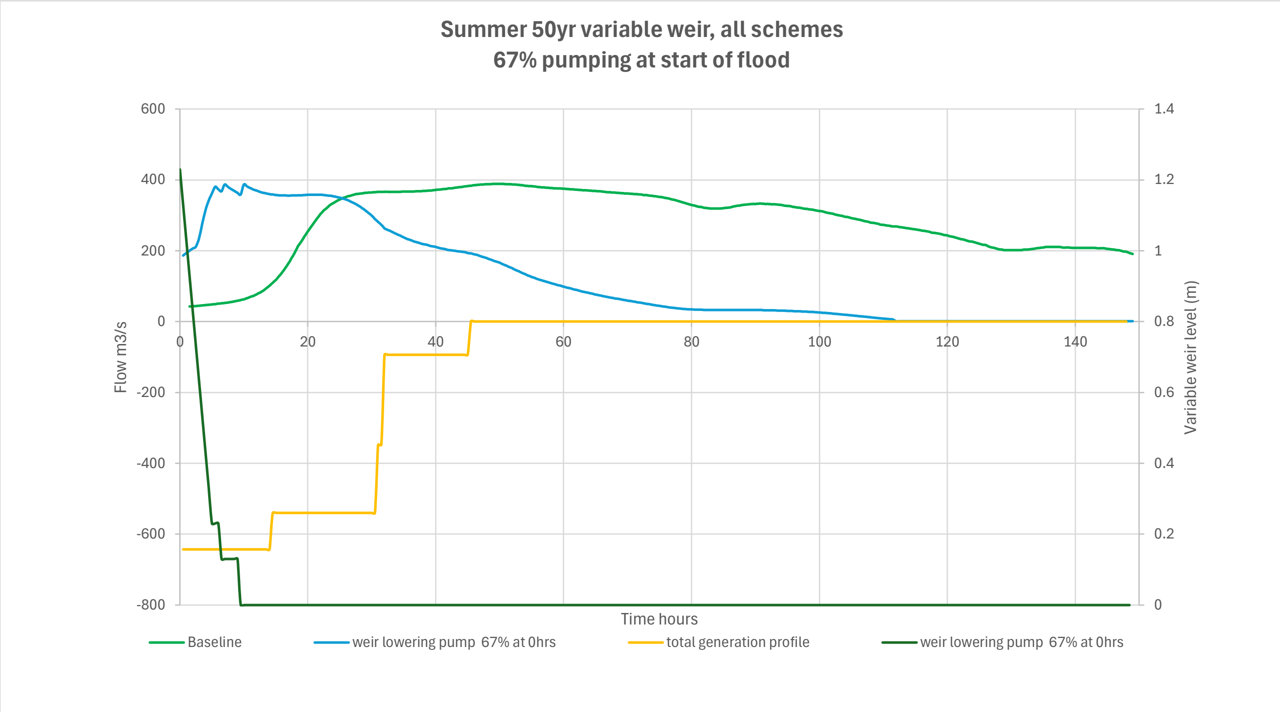


Figure 26: Summer 50yr, 1.23m variable weir, 67% pumping at start of flood – flow

Further modelling to explore flood alleviation potential

The modelling reported above aims to match the baseline downstream flows and not exceed the baseline peak water levels. In reality, the baseline flows and levels would not be known in advance of the incoming flood. Developing the control rules for the variable weir is more likely to anchor on minimising downstream flows subject to a maximum permissible level in the loch.

To accommodate the total generation volume of all existing and proposed schemes, a maximum weir raising of 1.23 is required, equating to a level of 16.96mAOD. Agreement of these maximum weir levels would form part of the detailed application and design of the Dochfour Weir proposal, however for the purposes of illustrating the flood alleviation potential of the variable weir arrangement in combination with pumping back to the headponds, it has been assumed that this is a maximum permissible level in Loch Ness (since this level does not cause any flooding issues). It is then possible to reduce the outflow as a potential improvement while ensuring that the loch level does not exceed this maximum level.

For example for the all schemes 100 year case, if the loch level is allowed to rise to 16.96m, and all schemes pump at 50% until the headponds are full, the downstream flow can be reduced to 240 m^3/s as shown in Figures 27 and 28.

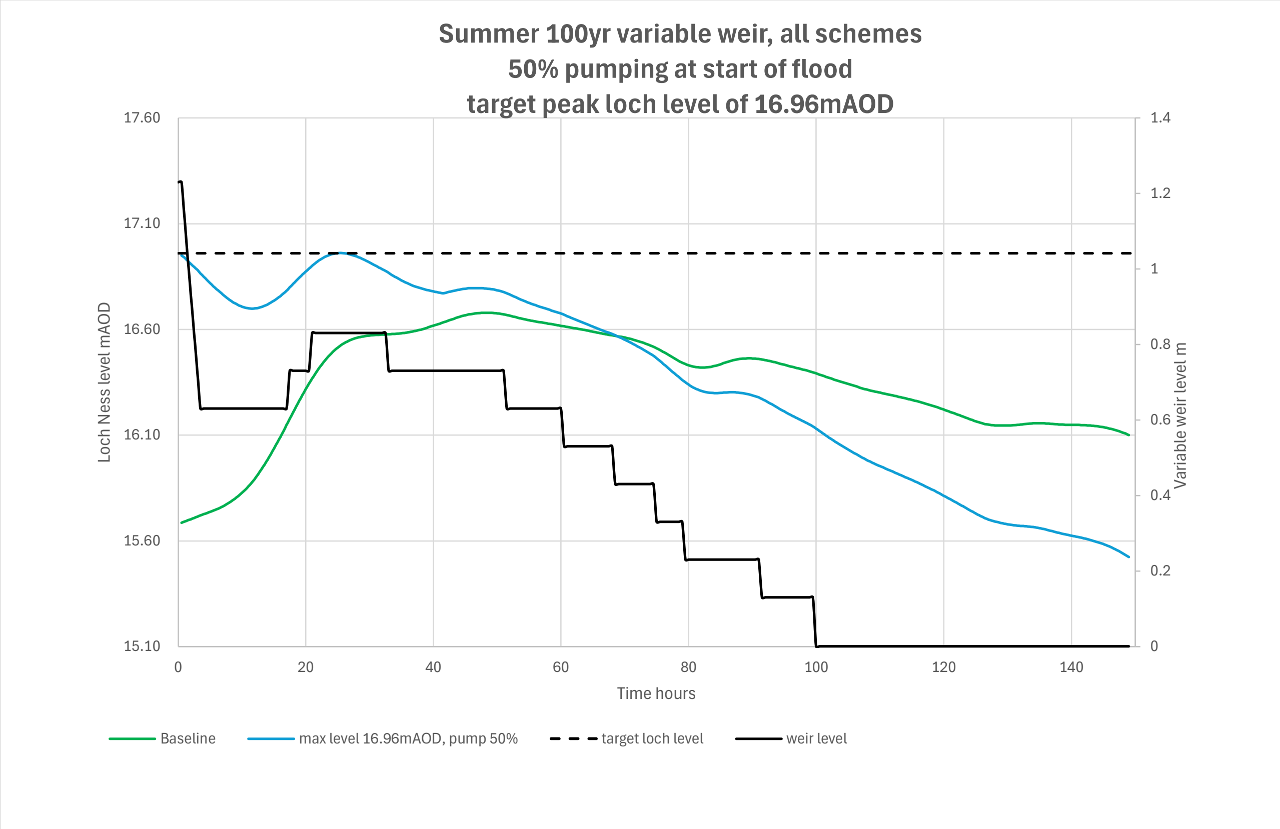


Figure 27: Summer 100yr, 1.23m variable weir, target peak loch level of 16.96mAOD, 50% pumping at start of flood – level

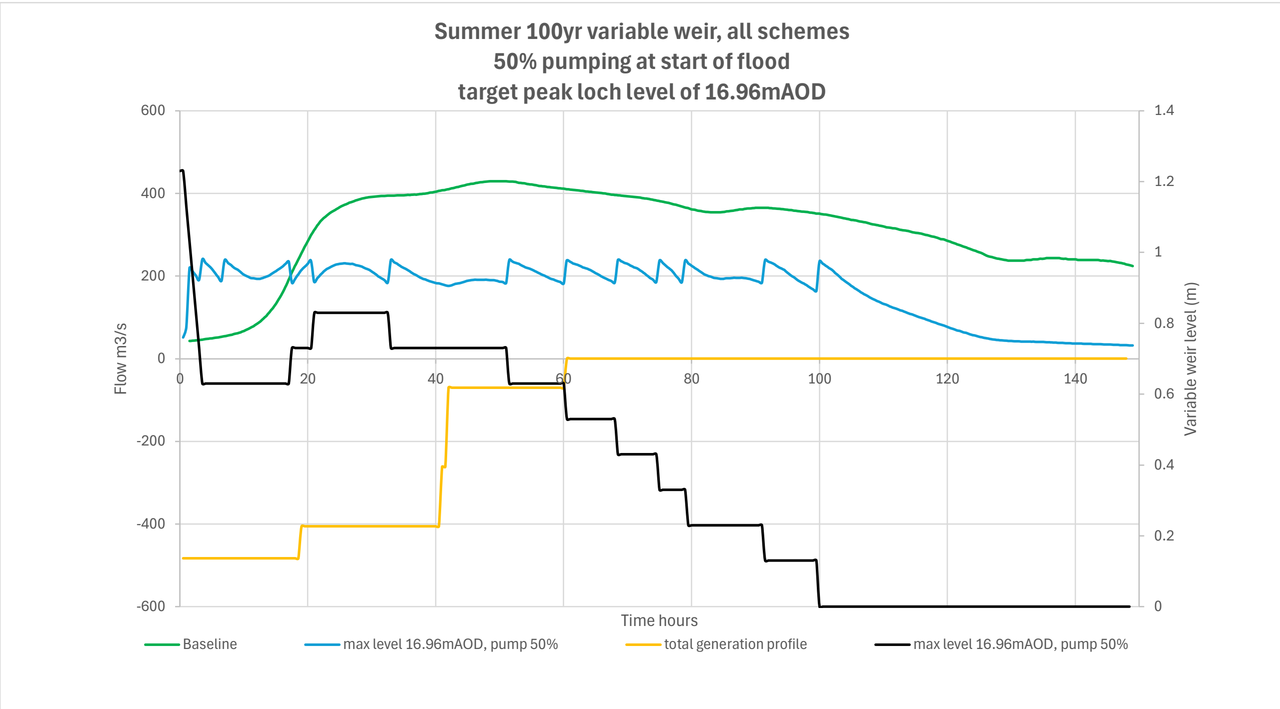


Figure 28: Summer 100yr, 1.23m variable weir, target peak loch level of 16.96mAOD, 50% pumping at start of flood – flow

Summary

The proposed variable weir is intended to operate between April and September such that it is raised by an amount that provides the storage equivalent in Loch Ness of the volume discharged through the turbines during generation. This will raise the levels in the loch but maintain baseline flows downstream in the River Ness.

Modelling of the behaviour of Loch Ness with the variable weir in the event of a summer flood has been undertaken for both the case of the Proposed Development operating only, and for the case of all existing and potential PSH schemes operating.

At the start of each simulation the weir is raised to its maximum level. Implicit in this assumption is that all schemes have previously undertaken a full generating cycle (i.e. full head pond storage has been discharged into Loch Ness). Based on assessment of market conditions, in general generation cycle duration will be between one and three hours with occasional longer duration generation cycles. A full cycle of 18 hours of generation at the Proposed Development and the equivalent for the other proposed schemes is therefore a very conservative assumption.

It should also be noted that the size of the Loch Ness catchment means that there will be significant lag between a storm event and the resulting runoff reaching Loch Ness. Such significant flood events that have been modelled would be the result of a large frontal rainfall system that would be forecast several days in advance. This means that in the scenario tested, the scheme(s) would be generating when very extreme rainfall is falling over the catchment, which also might be viewed as unrealistic.

As would be expected, controlling the downstream flows to match the baseline case by varying the weir level results in increased water levels in Loch Ness. For more extreme events, this could raise the loch to levels that cause flood risk to receptors around the margin of the loch. As the downstream flows are controlled, there is no increase in risk to receptors adjacent to the River Ness.

However, the modelling indicates that by combining operation of the weir to control downstream flows with leveraging the additional storage provided by the scheme(s) and pumping back to the headpond(s) to control loch levels, a reduction in both loch levels and downstream flows can be achieved.

A flood management plan could therefore be developed to address any flood risk impact and potentially provide a measure of flood alleviation for both Loch Ness and the River Ness.