FEARNA STORAGE

Fearna Pumped Storage Hydro Scheme
EIA Report

Chapter 3 – Consideration of Alternatives

February 2025

Quality Information

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Contents

3. Consideration of Alternatives and Design Evolution

Executive Summary

This chapter outlines the alternatives considered in the process of selecting the technology and the site for the Proposed Development. It also describes the key principles applied to design of the Proposed Development and the alternative designs of the individual scheme elements considered through the process of arriving at the proposed design.

Pumped Storage Hydro (PSH) is currently the only proven grid scale energy storage facility which can provide large scale Long Duration Electricity Storage (LDES). It is a mature technology, has low operational and maintenance costs and long operating lifespans.

PSH requires a suitable location combining several key factors:

- Suitable topography and geology to be able to create substantial upper and lower reservoirs and waterway system to provide meaningful Long Duration Electricity Storage [LDES] at scale.
- Practical access to the electricity transmission network;
- Practical access to the site; and
- The minimum footprint and impact of any effects on the natural environment from construction and operation of the scheme.

Several alternative sites were considered within a nationwide screening exercise undertaken over several years. The key criteria listed above are only satisfied at relatively few locations. The Highlands of Scotland do provide opportunities for PSH, however many potential sites have existing infrastructure or other stakeholder interests or environmental designations.

Plate 1 – PSH Projects Compared below shows the power and stored energy ratings of Fearna PSH (the orange diamond) compared with the four existing operational PSH projects in the UK (blue dots) and any PSH projects in development, that are in the planning system or consented but not constructed (green dots).

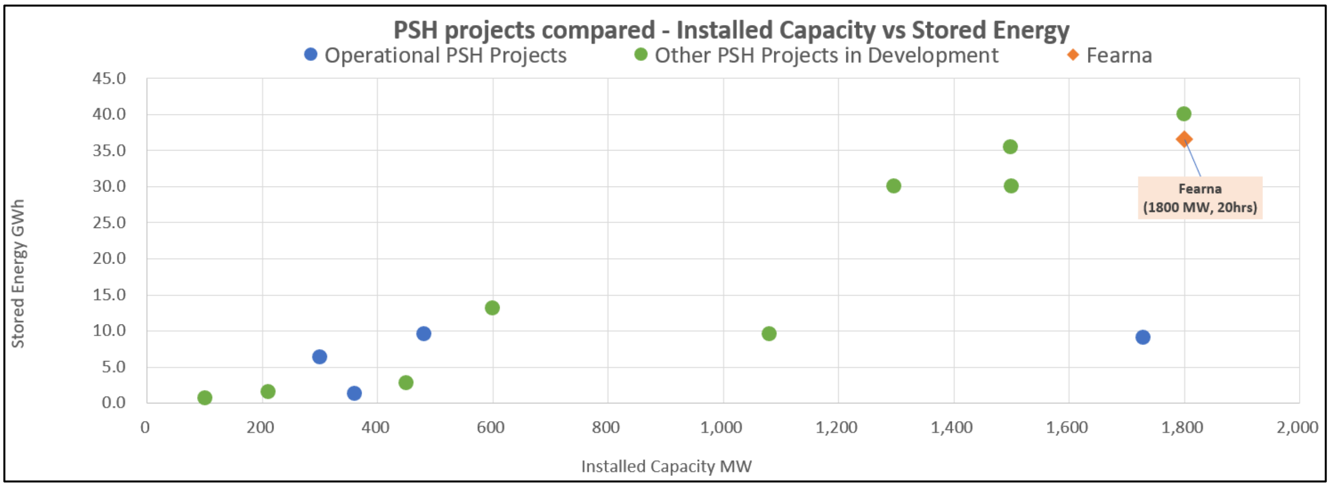

Plate 1 – PSH Projects Compared

The Proposed Development site would be technically favourable for PSH, with a high elevation (head) between the upper and lower reservoirs a short distance between the two reservoirs, thus requiring short tunnels, and apparently favourable geology.

The pre-existence of the lower reservoir as an existing and very large hydropower storage reservoir is also a key benefit. The lower reservoir is pre-made and sufficiently large that the Proposed Development can utilise it without any new dams or change to the current operating regime.

The creation of the Southern Access Route [SAR] would deliver a dedicated construction access which would largely use existing forest roads, which would vastly reduce the impact on the local road network and disturbance to the community.

Whilst any project of this scale will carry environmental impacts, the compact nature of the site in relation to the capacity and stored energy, re-use of existing infrastructure and the already heavily modified nature of the aquatic system would mean that the site compares favourably with other projects in development.

Material balance is key on any PSH project and the Proposed Development can demonstrate that no material would be required to be deposited off-site and only the required amount of rock to build the project would be excavated.

The Proposed Development would use a number of existing borrow pits to upgrade the SAR and also repurpose the disused quarry at the proposed powerhouse site to house the switching station switchyard.

The Proposed Development is an excellent candidate PSH site and would provide nationally significant electricity storage and generation potential and re-use existing infrastructure to achieve this. Despite its scale the footprint is among the most compact of any PSH site pro rate based on capacity and stored energy. When compared with other PSH projects it scores very favourably and is one of the best potential stores of grid scale energy in the UK for a relatively modest development footprint.

3.1 Introduction

3.1.1 This Chapter outlines the alternatives considered in the process of selecting the technology and the site for the Proposed Development. It also describes the key principles informing the design of the Proposed Development. Furthermore, it details the evolution of the design to account for:

- Consultees' responses in the Scoping Opinion and subsequently from the public and other consultees and interested parties;
- incorporation of the findings of site investigations and environmental surveys;
- further work on optimising the storage and generation capacity of the Proposed Development; and
- further engineering studies of the various scheme components.

3.1.2 This Chapter has been written by Gilkes Energy Ltd. A table presenting relevant qualifications and experience of key staff involved in the preparation of this Chapter is included in **Appendix 1.1 – EIA Specialist Team** in this EIA Report.

3.2 Technology Alternatives Considered

3.2.1 As the UK transitions away from a system dominated by large on-demand thermal and base-load nuclear to one dominated by intermittent renewables, it becomes increasingly challenging to balance the grid.

3.2.2 To make a meaningful difference to the future UK electricity system to balance intermittent wind and solar power, significant additional electrical energy storage capacity is required in terms of both dispatchable power, measured in Gigawatts (GW), and stored energy, measured in Gigawatt hours (GWh).

3.2.3 Weather patterns, especially wind, rather than the daily changes in demand, become the dominant factor. To balance longer consecutive periods of low wind or high wind (which can last many hours, or even days), long duration electrical energy storage is required.

3.2.4 Large-scale, long-duration energy storage 'LDES' is typically understood to mean anything above 6hrs duration, but recent energy market analysis undertaken by the energy consultancies LCP and Aurora suggests at least 12hrs storage is required in order to provide an optimum balancing service to the grid. So along with dispatchable power capacity at scale, large quantities of energy are also required. Grid scale batteries will not be able to meet this requirement.

3.2.5 PSH is currently the only grid scale energy storage facility which can provide such storage. It also has other advantages compared with alternative types of storage, such as batteries which only provide 1 to 2 hours of storage.

3.2.6 Other technologies such as compressed air storage and hydrogen may have been developed to prototype scale but have not yet been shown to be commercially feasible at meaningful scale.

3.2.7 PSH is proven technology, has low operational and maintenance costs and long operating lifespans.

3.2.8 PSH is by far the largest-capacity form of grid energy storage available, and, as of 2020, the United States Department of Energy Global Energy Storage Database[1] reports that PSH accounts for around 95% of all active tracked storage installations worldwide.

[1] https://gesdb.sandia.gov/, last accessed January 2025

3.2.9 By providing technologically proven and economic grid scale levels of LDES capacity with good dispatchability, PSH is the safest, most secure, sustainable and cost-effective way for integrating large-scale volumes of intermittent wind and solar generation into the electricity system.

3.2.10 PSH also provides other critical grid services, such as inertia, stability and black start. Black start is the process of re-energising the grid following a major blackout. Large hydropower schemes can produce generation on-demand in these circumstances which then allows other power stations to re-start.

3.3 Alternative Sites Considered

3.3.1 Pumped storage hydro for long duration electricity storage requires a site with the following attributes:

- Suitable topography to be able to create substantial upper and lower reservoirs, either by altering the level of existing waterbodies or by creating new ones;
- As high as possible an elevation difference between the upper and lower reservoirs;
- As short as possible a distance between the upper and lower reservoirs;
- Suitable geological conditions for reservoirs and waterways;
- Practical access to the electricity transmission network;
- Practical access to the site; and
- The minimum footprint and impact of effects on the natural environment from construction and operation of the scheme.

3.3.2 Based on the criteria outlined above, the Applicant has carried out a detailed screening study of the opportunities for developing pumped storage in the UK. The Proposed Development at Fearna would provide nationally significant quantities of both dispatchable power generation (up to 1,800MW) and stored energy (up to 36GWh). When compared with other PSH projects it scores very highly and is one of the best potential stores of grid scale energy in the UK and Europe.

3.3.3 **Plate 1 – PSH Projects Compared** below shows the power and stored energy ratings of the Proposed Development (the orange diamond) compared with the four existing operational PSH projects in the UK (blue dots) and any PSH projects in development, that are in the planning system or consented but not constructed (green dots).

3.3.4 Many other sites were considered in the Applicant's study, which are not shown in this chart as they did not score well against the study scoring criteria to take forward for development.

3.3.5 The Proposed Development's position on the upper, right-hand part of this chart shows it to be one of the most significant PSH development projects in the UK.

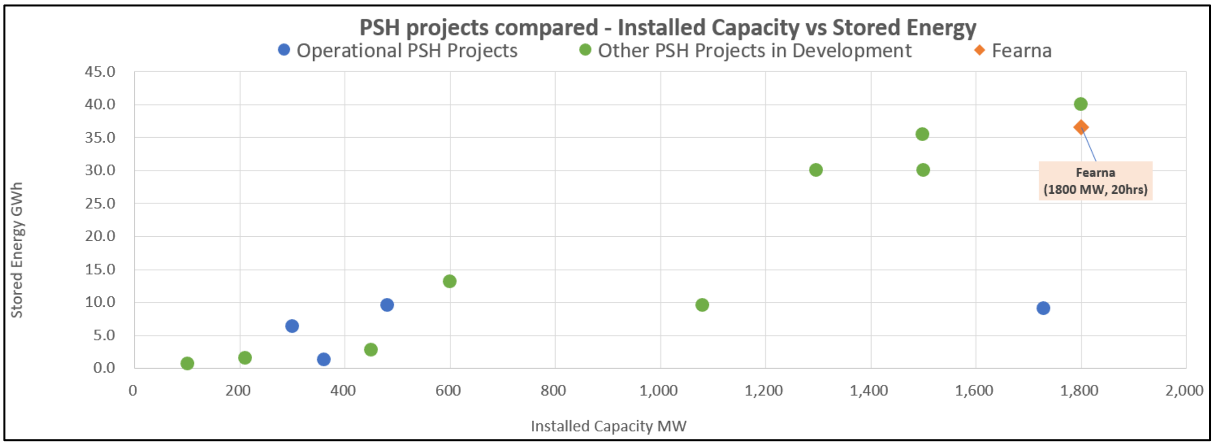

Plate 1 – UK PSH Projects Compared

3.3.6 The Proposed Development would utilise the existing Loch Quoich reservoir as its lower reservoir, which has the highest stored volume in the UK. Loch Quoich has also has very few ecological receptors in comparison to other large water bodies and having been dammed in the 1950s with no fish pass, is not a migratory fish route.

3.3.7 This provides the scheme with a large amount of storage capacity, which is governed by the capacity of the upper reservoir. At 1,800MW and 36GWh, the Proposed Development would use only around 11% of the available stored volume of Loch Quoich.

3.3.8 The Proposed Development can share the available storage volume with the existing Quoich conventional hydro scheme. It will operate within the existing operational range and will therefore not cause any additional dam spilling or drought conditions within the loch. With the upper reservoir creating additional storage within the same catchment, it actually provides more flexibility to mange levels in some scenarios.

3.3.9 There are no environmental designations within the Proposed Development site.

3.3.10 The design of the development has been developed to achieve a balance of earthworks within each within discrete works areas i) the SAR ii) lower works and iii) upper works, hence minimising its footprint and haulage of materials within the site and removing the requirement for bulk haulage of earthworks materials off site.

3.3.11 The factors above combine to provide the rationale for the proposed site being the preferred location for the Proposed Development.

3.3.12 Within the site, different configurations were considered, primarily of the position of the powerhouse and lower works area. This process is described in the following chapter.

3.4 Key Design Principles

3.4.1 The key principles on which the design of the Proposed Development is founded are as follows:

- Sizing the capacity of the scheme to maximise the opportunity of the site for the purpose of long term electricity storage;
- Design and location of the scheme components to minimise any impacts of the Proposed Development on the natural environment;
- Planning the construction and operation of the Proposed Development to minimise any negative effects on users of the site and communities local to and more distant from the site;
- Carefully designing and locating permanent above-ground features to minimise landscape and visual effect and to optimise the opportunity for mitigation measures;
- Sizing and designing the scheme components to adequately meet their functional requirements within the minimum design footprint;
- Optimising constructability and minimising the construction programme duration which would minimise local disruption;
- Designing the mass balance and spoil management of materials within the site such that wherever possible construction materials are won from within the site and materials displaced by the construction are put to beneficial use within the site;
- Prioritising sustainable construction principles;
- Consider the existing site uses and characteristics; and
- The safe construction, operation and decommissioning of the Proposed Development.

3.4.2 The proposed Development scored highly against the above criteria, the key principles being the ability to build a technically feasible large capacity store of potential electrical energy, close to the main grid network, with a relatively modest footprint on existing habitats, away from designated natural protection sites and relatively limited visual and other local impacts.

3.5 Alternative Design Options Considered

3.5.1 For the scheme itself and for each of the key components of the Proposed Development, the alternatives considered during the feasibility design stage (pre-scoping) and thereafter during the post-scoping design development are described in the following paragraphs:

Scheme Capacity

3.5.2 The UK will likely need many hundreds of GWh of new large scale long duration electrical energy storage (LDES) as the system transitions to rely on mainly intermittent renewables rather than fossil fuels. For this reason, the scheme generation and storage capacitieswere maximised in the early stages of scheme design.

3.5.3 In order to meet this requirement, it is logical to maximise the benefit of feasible (LDES) opportunities and therefore, any good natural PSH energy storage sites should be utilised within their reasonable physical and environmental constraints, to maximise the benefit to the national grid for minimum development footprint.

3.5.4 The Request for Scoping Opinion showed a scheme capacity of 2000MW and with a storage capacity of 36GWh. This would provide the equivalent of 18 hours of generation at maximum capacity.

3.5.5 Further assessment and engagement with the Transmission Owner (SSE Transmission) and National Electricity System Operator identified that there are regulatory grid considerations on generation capacities higher than 1,800MW. This is due to impact on the network of losing a large amount of generation from a single point in the event of a fault.

3.5.6 Further detailed design and assessment also identified that an 1,800MW capacity was technically and financially favourable in comparison to 2,000MW. 1,800MW requires less underground works and improves the constructability of the project.

3.5.7 For the above reasons, the Proposed Development planning application is being submitted with a capacity of 1,800MW and storage capacity of 36GWh.

Scheme Options and Layout Selection

3.5.8 Several scheme options were considered during the evolution of the design. These were subject internal design review and additionally by environmental and technical consultants.

3.6 Design Development of the Scheme Layout by Component

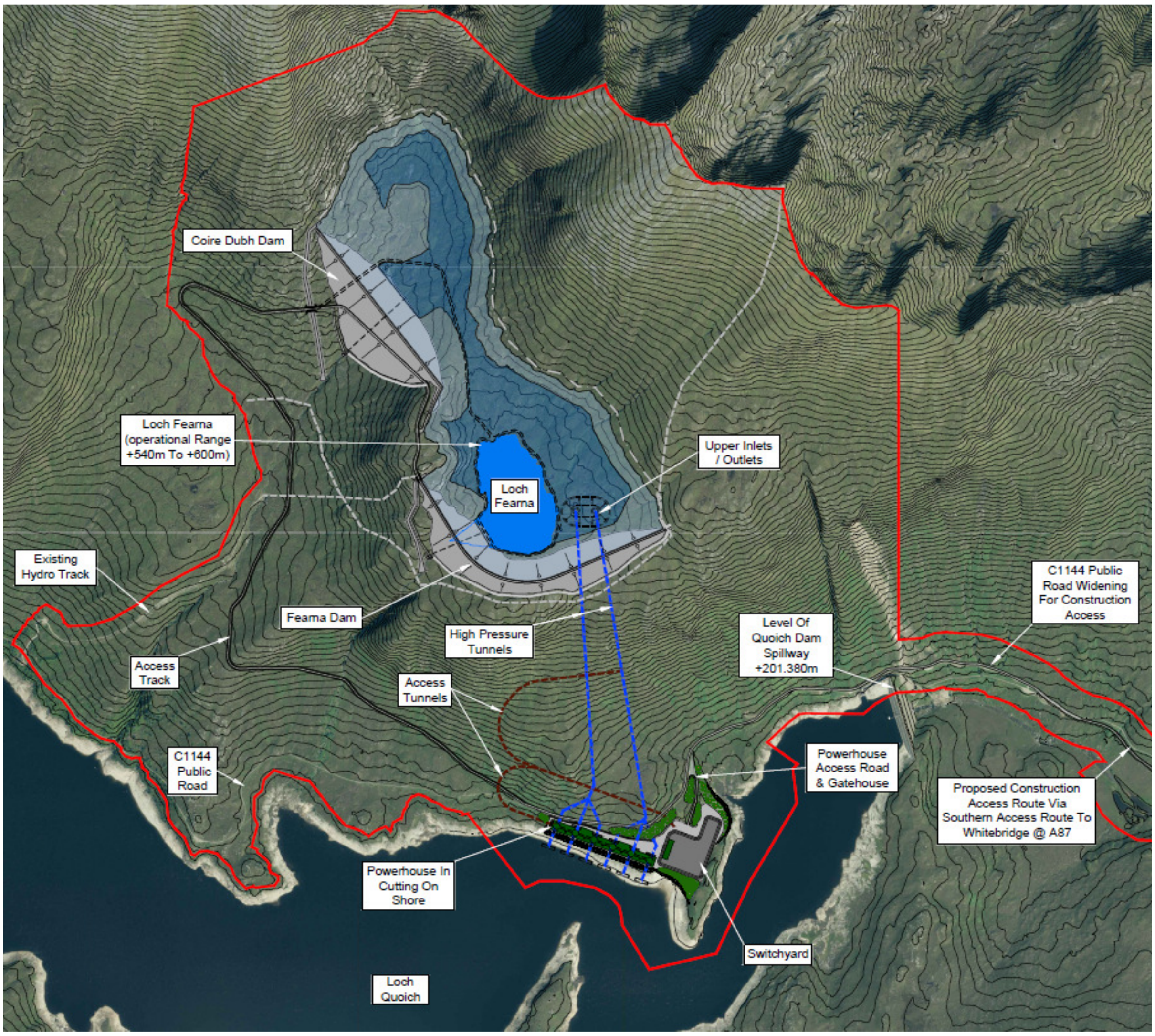

Plate 2 - Preferred Option FC4 Scheme Layout Plan (extract from Figure 2.3)

The Lower Reservoir

3.6.1 Loch Quoich acting as the lower reservoir is the only feasible option. There are no feasible water bodies situated below the elevation of Loch Quoich that could have acted as an alternative lower reservoir.

3.6.2 Calculations showed that the existing reservoir, created in its current form in the 1950s by the damming of the Gearr Garry, was large enough to support a new pumped storage scheme coexisting with the ongoing operation of the Quoich Hydro scheme and having no impact on flooding or compliance with current CAR licenses.

The Upper Reservoir and Dam Type

A screening exercise for other potential upper reservoir sites was conducted around the full perimeter of Loch Quoich, however only one feasible site was identified.

3.6.3 For the upper reservoir, the existing Loch Fearna and the adjacent Coire Dubh are situated at the same elevation, thereby providing a feasible upper reservoir location. This is also located at the eastern end of Loch Quoich and therefore closest to the existing national grid and road infrastructure.

3.6.4 The available storage of the lower reservoir is very large at around 360 million cubic metres, therefore the governing parameter on the scheme storage and MW capacity would be the capacity the upper reservoir.

3.6.5 The storage volume created was analysed using dams at varying crest levels. The upper reservoir height has apparently favourable ground conditions to construct concrete-faced rockfill dams, which would be the preferred height.

3.6.6 Topographical survey and borrow pit design was carried out to calculate the potentially available volumes of rock that may be available from within the proposed inundation area for the construction of the dams. The quantities of overlying peat and superficial material were assessed using a combination of desktop and site review, as well as the results of the extensive peat probing exercise.

3.6.7 The borrow pit design includes only borrow pits within the upper reservoir inundation. The visual and logistical implications of winning stone from sources outwith the upper reservoir were deemed too significant.

3.6.8 The analysis showed that creating dams to achieve a maximum water level of +600mAOD provided and optimal balance of storage volume and available rock.

3.6.9 The upper reservoir would require the construction of two dams: i) Fearna Dam; and ii) Coire Dubh Dam. Each of these would likely be of Concrete Faced Rockfill Dam [CFRD] construction. The remainder of the upper reservoir is created by the natural hillside behind, thus making best use of the natural topography.

3.6.10 Other dam types have been considered but discounted in favour of CFRD. Roller Compacted Concrete (RCC) dams have a smaller footprint and volume than CFRD dams, but would however require significantly more concrete and thus imported cement and increased carbon footprint.

3.6.11 Earth embankment dams were also considered however the geology of the Proposed Development site shows insufficient volumes of available material. Additionally, the shallower faces of this dam type would require a much larger footprint and higher volume of material than CFRD dams.

3.6.12 CFRD dams have therefore been selected as the preferred dam type, with the required rock material (quality and quantity) expected to be available within the upper reservoir. Furthermore there is the ability to accept any surplus rock material from other areas of the site.

3.6.13 Both the Fearna and Coire Dubh dams would have spillways and discharge channels, to allow the transfer of flood flows over the dams and back to the existing watercourses, should flood events occur in tandem with the upper reservoir being at its maximum level. These spillways would be of similar form and construction to the existing Quoich Dam spillway channel, with a concrete structure to the side of the dam and a discharge channel excavated into the rock.

The Fearna Dam

3.6.14 The Fearna Dam would be built along the southern and eastern edges of Loch Fearna. The dam has an approximate 90 degree change in alignment reflect the ridgeline behind which it sits.

3.6.15 Several dam alignments and positions were considered during the design development. The earlier concepts had the dam positioned on the ridgeline to the south and the dam comprised a series of straight lines, which were expected to be easier to construct.

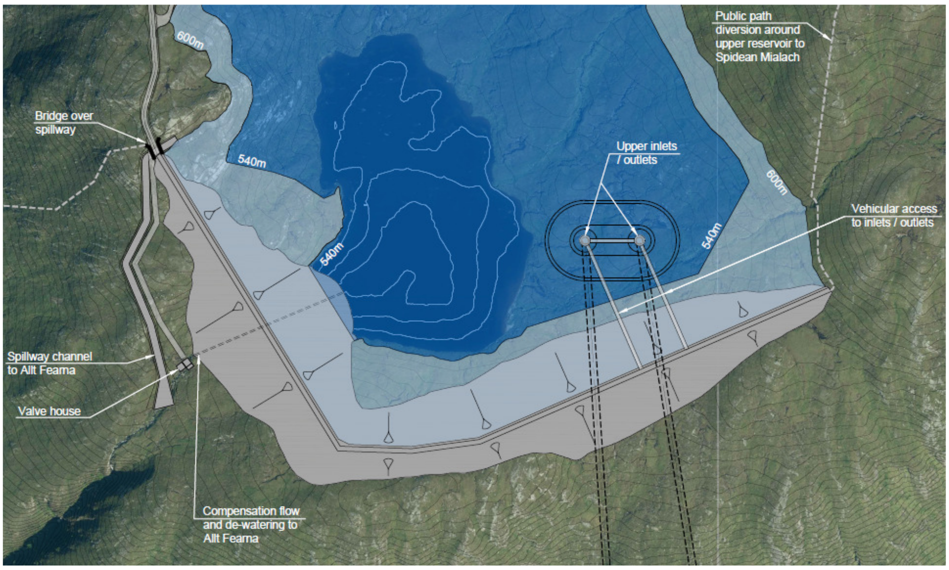

Plate 3 – Preliminary Fearna Dam arrangement with straight edges

3.6.16 Following input from the landscape and visual specialists, dam engineers, and further design development, the dam alignment was amended to become curved.

3.6.17 This amendment reduced the visual impact, footprint and dam volume, whilst also improving the dam stability. There was a modest reduction in storage volume as a result, however the benefits of the proposed change outweighed the reduction in storage.

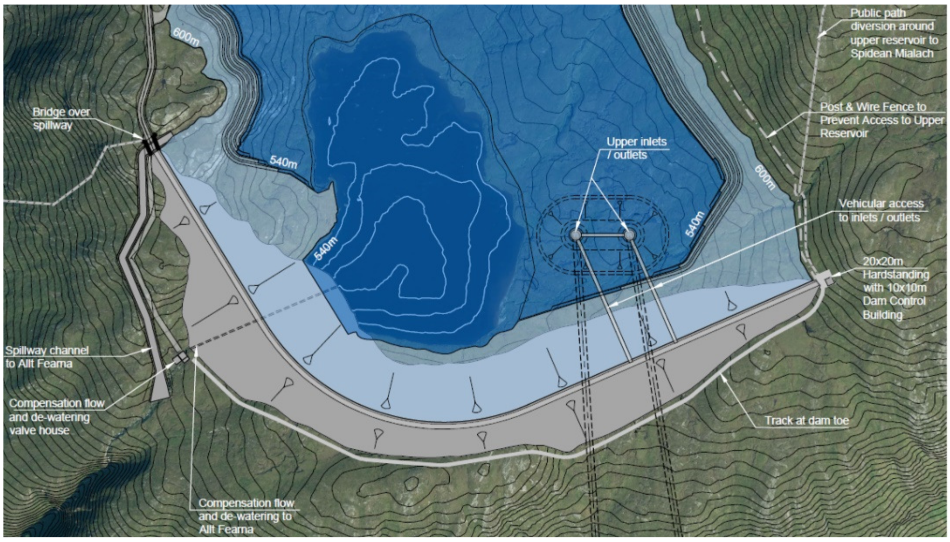

Plate 4 – Revised Fearna Dam arrangement with curved face

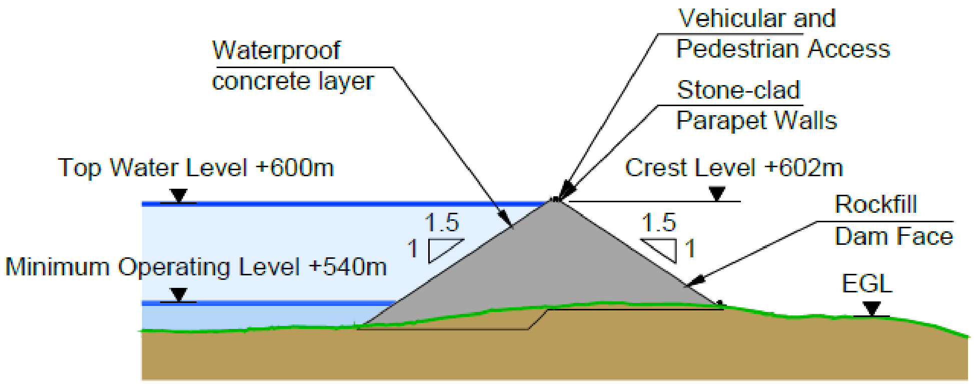

Plate 5 – Fearna Dam – Cross Section

3.6.18 In order to facilitate the construction of the Fearna Dam, a partial dewatering of Loch Fearna is proposed, which would reduce the loch depth and area to allow space to construct the dam. Temporary construction diversion would pass flows out of the loch to the Allt Fearna watercourse downstream, bypassing the dam works.

The Coire Dubh Dam

3.6.19 The Coire Dubh Dam would sit generally on an east-west orientation across the southern side of Coire Dubh. This coire is characterised by steep, exposed rock slopes with thin overlying soils in some areas. There are some peat deposits in the base of the quarry however these are in manageable quantity and depth.

3.6.20 The position of the dam was optimised by considering the ground conditions, material availability, constructability and storage volume.

3.6.21 The dam design was subject to several minor design iterations, mainly of the orientation and alignment at the eastern end. The final design solution retains a straight alignment along the majority of its length with a dog-leg at the eastern end to raise the ground level locally in this area. This simplifies the structure and avoids complexity in the dam design.

3.6.22 The access track to the upper reservoir would cross the downstream face of the Coire Dubh dam diagonally. This design allows the track to reach the required level without diverting across the open hill, avoiding switchbacks and major earthworks. Using the dam face for access is a common approach on CFRD dams globally.

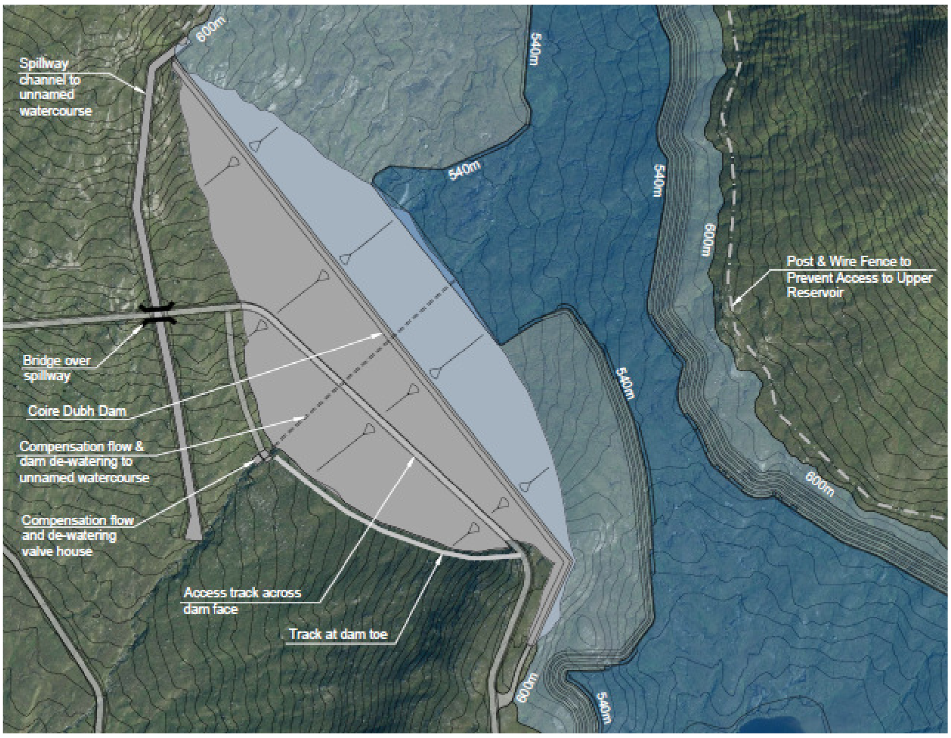

Plate 6 – Coire Dubh Dam - Plan

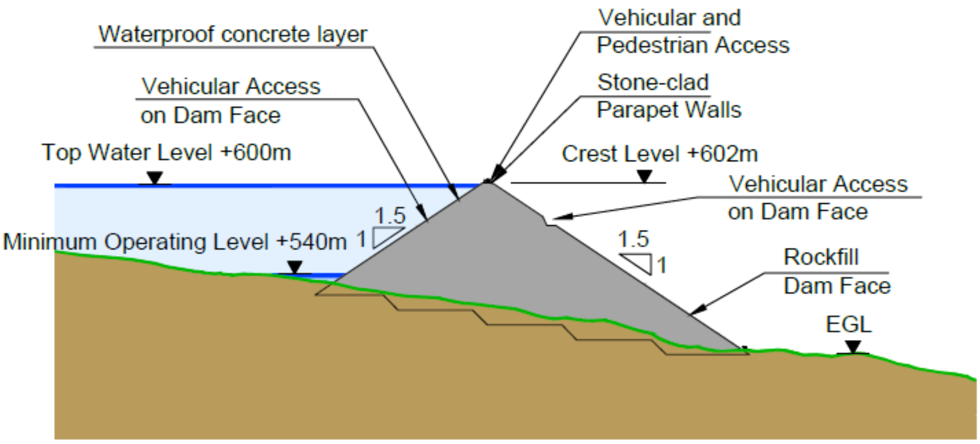

Plate 7 – Coire Dubh Dam – Cross Section

The Upper Control Works

3.6.23 The Upper Control Works fulfil two functions: i) screening to prevent debris entering the tunnel system and impacting on the performance of the pump-turbine units; and ii) the ability to stop water entering the tunnels, using isolation gates.

3.6.24 The structures require to function over the full drawdown range of the upper reservoir, which is 60m in vertical height. Additionally, the base of the structure requires to be set below the minimum operating water level, to prevent air being drawn into the system.

3.6.25 During the development of options, several alternative designs were considered. At a high level, two options were available: i) fully submerged; and ii) partially submerged.

3.6.26 Fully submerged structures would be designed to remain below the minimum water level at all times. Whilst this would be visually preferred, operationally it introduces complexity and health and safety issues. Access to the structures would require a full dewatering of the reservoir and/or divers, depending on the operation required and this could cause operational problems, particularly in an emergency situation.

3.6.27 Partially submerged structures would allow access at any operating level via gantries from the dams to the control structures. These structures would however always have infrastructure visible above the water level.

3.6.28 Based on the above, the Proposed Development would include a partially-submerged solution.

3.6.29 Options for the type and form or partially-submerged structure options were then developed. In order to minimise visual impact and construction complexity, simple, clean shapes are preferred. Examples of other PSH projects were reviewed and circular, silo-type structures would be applicable to the Proposed Development.

3.6.30 The structures would be constructed from reinforced concrete using site-won aggregate material. The peaty water within the upper reservoir would stain the concrete, similar to the adjacent concrete upstream faces of the dams, which would reduce their visual impact.

3.6.31 Gantries would be required to provide vehicular and pedestrian access to the structures to allow operation and maintenance. These would likely be of steel or concrete construction and sensitively designed to provide robust access in this harsh environment, yet with the minimal visual impact.

3.6.32 Two upper control structures would be required, one for each pressure tunnel. The structures would be sited directly over the vertical pressure shafts, which is a requirement of the hydraulic design.

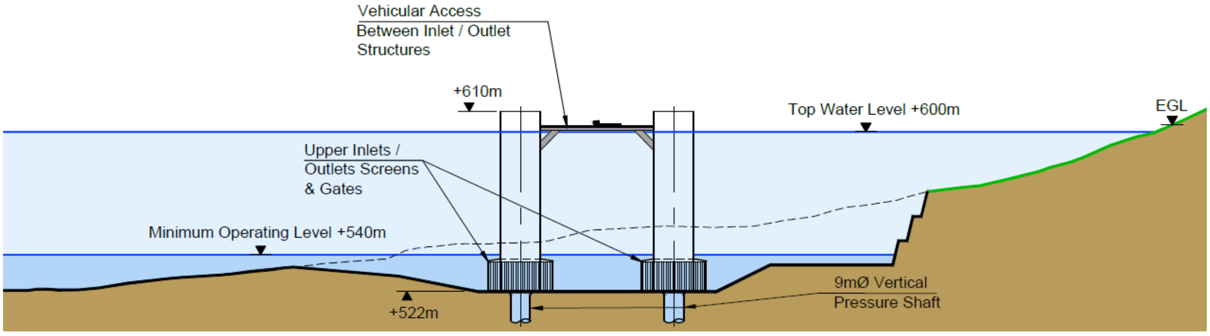

Plate 8 – Upper Control Works Arrangement (extract from Figure 2.7)

Powerhouse Type

3.6.33 The proposed 1,800MW capacity pumped storage scheme would be served by up to six reversible pump-turbines, each of nominal 300MW generating capacity. In pump mode, the units would spin using excess electricity imported from the grid network to pump water from the lower reservoir to the upper via the tunnel system. In generation mode, the units would spin in the opposite direction, driven by the water which would be transferring down from the upper reservoir to the lower.

3.6.34 Different options have been considered for the powerhouse configuration which would house both the pump turbines and associated electro-mechanical equipment.

3.6.35 The hydraulic arrangement and performance of the pump-turbine units is complex and is a key driver for the arrangement of the Proposed Development and in particular the powerhouse and lower works area. The hydraulic impacts during events such as grid fault or when units are switching between pump and turbine mode create the most onerous conditions, with higher pressures (water hammer) created within the system and the units running temporarily to higher speeds.

3.6.36 Additionally, the Proposed Development would co-exist with the existing Quoich hydro scheme. The design therefore requires to consider the current full operating range of Loch Quoich, which is approximately 26 metres. The minimum operating level of Loch Quoich therefore dictates the level at which the pump-turbines would be located.

3.6.37 The pump-turbine units have to be sufficiently below the minimum level of Loch Quoich to prevent them drawing in air along with the water, which would cause major damage and cause the scheme not to function.

Cavern versus Shafts

3.6.38 PSH projects typically have a powerhouse either: i) on the shore of the lower reservoir ('shaft-type'); or ii) within a series of underground caverns. Both options have been considered in the design of the Proposed Development.

3.6.39 The Proposed Development site has favourable geology on the shoreline of the lower reservoir which would house a shaft-type powerhouse. This is supported by surface observations and also the presence of the disused quarry which was used to create the Quoich Dam in the 1950s.

3.6.40 The proposed access tunnel to the base of the powerhouse shafts would improve the construction and operational access.

3.6.41 The tunnel lining requirements are typically more onerous on shaft-type arrangements than caverns as they typically require more steel lining, but this carries no planning-related impact.

3.6.42 A powerhouse superstructure would be required to cover the shafts and also provide a gantry crane to install and remove equipment, together with offices, welfare, maintenance and storage facilities.

3.6.43 The alternative cavern system would be set deep underground and require a series of access, hydraulic, ventilation and cable tunnels to service the underground powerhouse complex. Whilst this would avoid the need for the powerhouse structure on the loch shore, the external HV switchyard would still be required, as would a number of additional tunnel portals and also the lower control works within Loch Quoich.

3.6.44 Surge shafts on the downstream side of the powerhouse caverns would also likely be required, which would potentially add six shafts to the open air And which would come to the ground surface on challenging topography and potentially close to the existing Skye transmission line and its proposed replacement.

3.6.45 Underground works typically carry much higher costs, risks and programme durations that excavations carried out from the surface. Further, underground works are caried out by a more limited number of contractors and therefore this would restrict the available supply chain to a degree.

3.6.46 After careful consideration of the pros and cons of each powerhouse type, the Proposed Development would adopt a shaft-type powerhouse, with recognition that a powerhouse structure would be required and therefore the design of the powerhouse should be carefully considered. Refer to **Appendix 2.1 – Sustainable Design Statement** for further information.

Powerhouse and Lower Works Area

3.6.47 Following the decision to proceed with a shaft-type powerhouse, potential powerhouse locations were identified and assessed.

3.6.48 Key criteria applied to this process include: i) site topography; ii) site geology; iii) material balance; iii) access; iv) visual impact; v) impact on existing infrastructure; and vi) reuse of existing infrastructure.

3.6.49 The assessment identified three potential powerhouse positions, as identified in plate 9

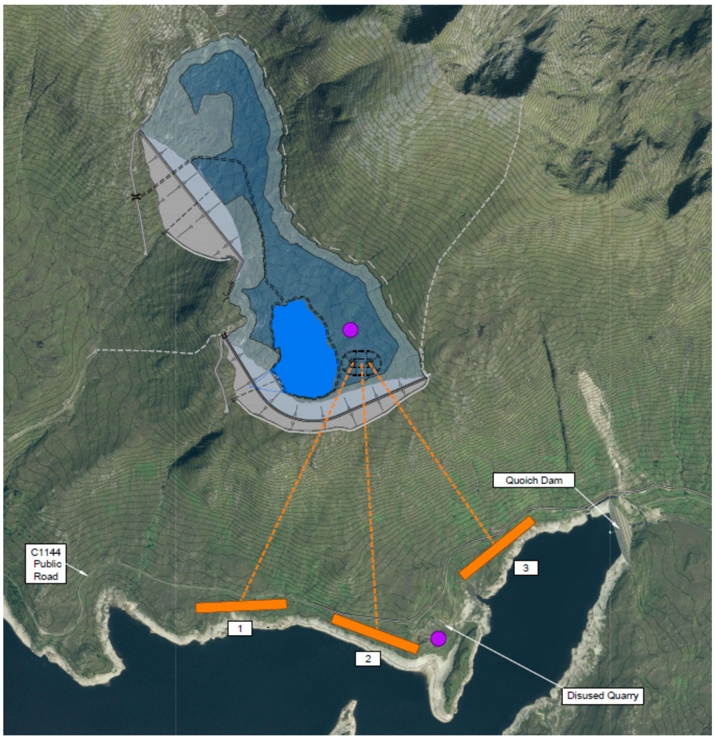

Plate 9 – Powerhouse Location Options

3.6.50 Powerhouse position 1 would be located on a sloping area of ground which would be excavated to be level between the C1144 public road and the edge of Loch Quoich. The topography is however steep in this area and the structure would be exposed and highly visible.

3.6.51 Review of the available geological data however showed the presence of a geological fault in this area, which would not only impact on the powerhouse structure but also the underground tunnel system.

3.6.52 Powerhouse position 2 would be located on a terrace adjacent to the disused quarry which was used to construct the Quoich dam in the 1950s. The terrace would provide sufficient space to accommodate the structure without modification to the C1144. Additionaly, the structure would sit below the road and be screened to an extent from passing road users. The structure would however be more visible to the east than position 1.

3.6.53 The site of position 2 has visible rockhead across the footprint and along the shoreline, where the lower control works require to be built within Loch Quoich.

3.6.54 Review of the geology showed that this location is away from the geological fault which would affect position 1. Further intrusive ground investigation would be required to provide this. However, the adjacent quarry provides a very useful reference to what may be expected at the adjacent structure.

3.6.55 Position 3 provides the shortest distance between the upper and lower works and would therefore require the shortest tunnels. Locating the powerhouse in this position would require a diversion of the public road, which would be challenging considering the surrounding topography. The presence of the transmission line to Skye would also present a challenge.

3.6.56 Geologically, this option carries risks in relation to noise and vibration, with the presence of the Quoich dam and the 2018 landslide in close proximity.

3.6.57 The interface with Quoich Hydro operations would be complex at this location, with both projects having hydraulic structures within Loch Quoich in close proximity to each other.

3.6.58 The assessment of each option against the stipulated criteria identified a clear preference for Powerhouse Position 2. In addition to the powerhouse position being preferred, the area within the disused quarry could accept the material arisings from the powerhouse excavations. This area already has significant man-made impacts and has been used for material storage and equipment, as well as boat access to Loch Quoich.

3.6.59 Material placement within the quarry would raise the level of the area to be outwith the inundation zone of Loch Quoich, thereby creating a site compound and processing area during construction which would then become the HV switchyard.

3.6.60 Access to this area from the C1144 already exists in the form of a small access track, which would be useful for ground investigation and early mobilisation works. A new, larger access track would however be constructed.

3.6.61 A portal to the access tunnel and high pressure tunnel network would be constructed off the back face of the quarry. Excavated material would then be processed for re-use at the working area within the quarry.

3.6.62 To mitigate visual impacts, a suite of measures including the creation of screening landforms, vegetated shoreline, native tree planting and sensitive powerhouse design using site-won materials for roofing and facades would be proposed. Refer to **Figure 2.12 – Powerhouse Area Plan and Appendix 2.2 – Sustainable Design Statement** for further information.

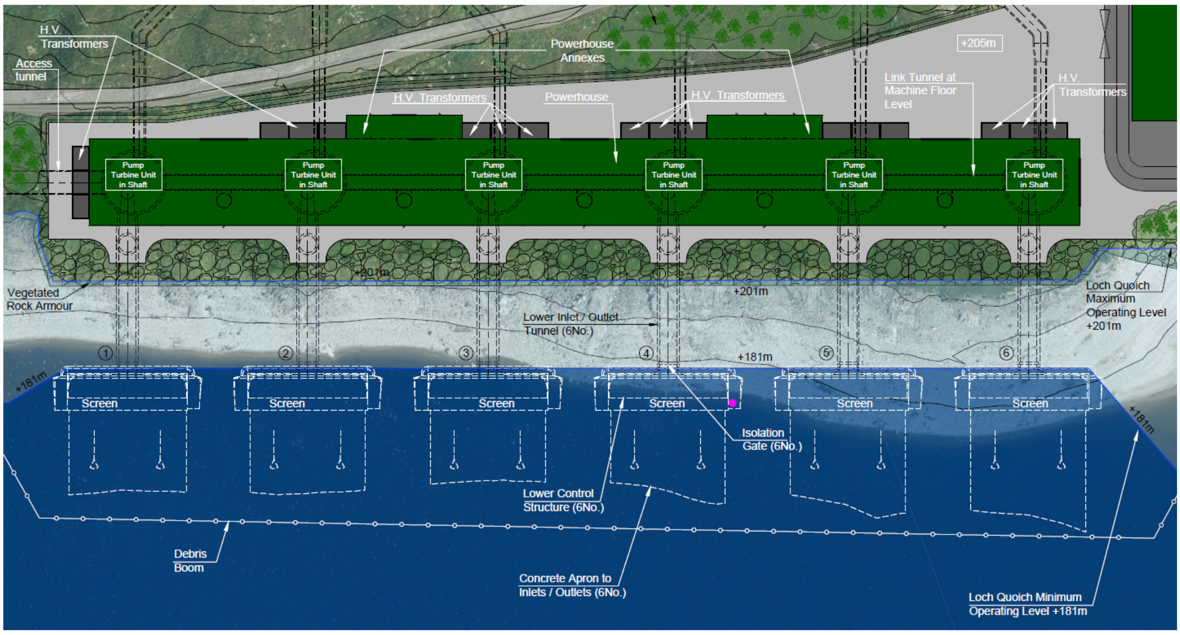

Plate 10 – Powerhouse and Lower Control Works Plan (extract from Figure 2.11)

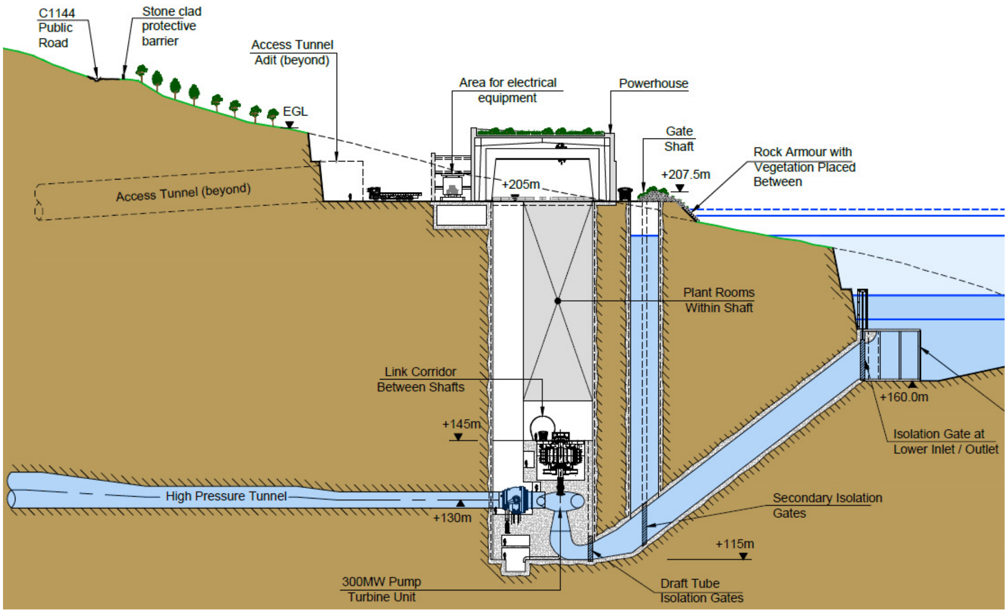

Plate 11 - Typical Powerhouse Cross Section (extract from Figure 2.13)

3.6.63 The architecutre of the powerhouse concept has been developed in close collaboration with the project Architects and Landscape Architects. Refer to **Appendix 2.1 Sustainable Design Statement** for more information on the process which has been followed to arrive at the proposed concept.

3.6.64 The solution developed reflects a number of references including landcape features, the surrounding natural environment and existing site uses.

3.6.65 Several alternative options were considered, with the preferred approach to blend the powerhouse with the surrounding landscape by using a green / vegetated roof and with the building facades constructed using rock which has been excavated from the site.

3.6.66 Over time the facades will weather and moss and lichens will grow, similar to the downstream face of the Quoich dam and the other masonry-faced structures associated with the existing Quoich hydro scheme. The building will effectively mature into the surroundings, despite being a large structure.

The Lower Control Works

3.6.67 The Lower Control Works would transfer water into and out of Loch Quoich. These structures require to be located beneath the minimum operating level of Loch Quoich and out into the loch to allow them to function properly at all levels.

3.6.68 As Loch Quoich is a constantly fluctuating operational hydro reservoir, constructability and the temporary marine works are a key consideration in the design.

3.6.69 To minimise the scale and visual impact, submerged concrete structures would be proposed. As with the upper control works, submerged structures introduce some complexities, however the elevation and conditions at the lower end of the site are less extreme, access is better and maintenance activities should be very infrequent. Additional isolation gates would also be provided nearby at the pump-turbine units.

The Underground Waterway System

3.6.70 Several options were considered for the number and sizing of the underground waterway tunnels and shafts.

3.6.71 A number of factors influence the design of the underground works, including: i) design flows; ii) frictional head losses; ii) geology (assumed at this stage); iii) topography; iv) material quantities; v) powerhouse and upper control works positions; and vi) construction methodology and programme.

3.6.72 The above factors require to be considered and balanced to produce appropriate design options. These options are then refined to a preferred option. It should be noted however that in the absence of intrusive ground investigation, detailed numerical analysis and civil contractor engagement, the proposed underground works are considered to demonstrate a feasible solution at this stage.

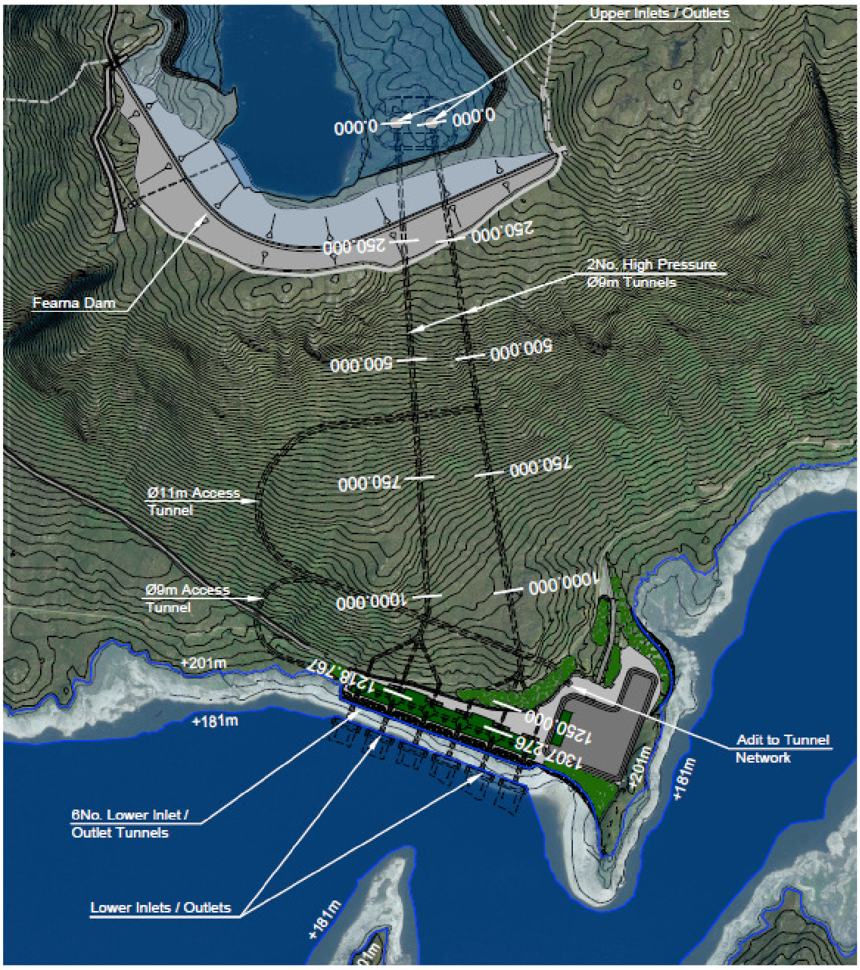

Plate 12 Tunnel Layout (extract from Figure 2.8)

3.6.73 Two main pressure tunnels are proposed. These would each provide water to three pump-turbine units. On each system, a vertical shaft would be provided at the upper end, with the upper control works placed directly above. At the bottom of the shafts, the tunnels would follow a gradient prior to a flat section towards the powerhouse. As the tunnels split to feed each pump-turbine unit, the tunnel diameters would reduce.

3.6.74 In the past, high pressure hydropower tunnels have in some cases been left unlined. Whilst this is technically feasible if conditions allow, the consequences of issues should they occur are typically very significant and likely to make the asset inoperable. Unlined tunnels are therefore not considered appropriate for the Proposed Development.

3.6.75 The vertical shafts and upper ends of the main pressure tunnels would be lined in concrete. The lower sections would be lined in concrete and then steel due to the high internal water pressures compared with the external rock pressures.

3.6.76 The two main pressure tunnels would be in the order of 9m diameter. This would reduce in one or two stages to approximate 3.5m at each pump-turbine unit.

3.6.77 The access tunnel would be constructed prior to the pressure tunnels, to allow rock to be extracted and the tunnel linings installed. This tunnel would require to be slightly larger than the pressure tunnels to allow the welded steel rings to be transported down the tunnel to the high pressure section and avoid ventilation and other temporary services.

3.6.78 The access tunnel also has a spur to the powerhouse shafts and which would continue through all six shafts. This would increase the efficiency of the powerhouse construction, by allowing the removal of material from the base of the shafts and transported out, as opposed to be craned out from the surface.

Access to the Site – Port to Invergarry

3.6.79 Materials, plant and equipment imported from overseas may travel to the site via the port of Corpach or Inverness, after which it would be transported via the trunk road network to Invergarry. This is covered in **Chapter 17 – Transport and Access**.

Construction Access from the A87 to PSH Site

3.6.80 The Proposed Development is located approximately 23km west of Invergarry in a remote location. Two potential access routes were identified i) the C1144 public road, which joins the A87 trunk road to the west of Invergarry; and ii) an off-line access route using existing forest roads, which would require some upgrades, and extended by approximately 4km of new track to reach the site.

3.6.81 The C1144 route was considered in its current form with a view to its use as the primary construction access for the Proposed Development. This route is a single lane road with passing places, which provides access to Glen Garry for residents, tourists, council services etc. It is a developed route which appears to have been surfaced and upgraded at various stages, rather than being a purpose-built road.

3.6.82 The horizontal and vertical alignment and current width of the C1144 is not appropriate for the construction of the Proposed Development in its current form. It would require significant upgrades to a dual-lane road, with the load capacity of the structures and current roadway likely being incapable of carrying significant construction traffic.

3.6.83 The Applicant is also aware that the C1144 is the proposed access route for the Skye Reinforcement transmission project, which may overlap with the Proposed Development programme. It may also be used for the construction of the grid connection works for the Proposed Development.

3.6.84 Selection of the SAR over the C1144 for construction of the Proposed development and any significant use during operation and maintenance has been driven by a number of factors:

- Reduced ecological impacts, particularly on the West Inverness-shire Lochs SPA and SSSI.
- Minimising disruption to members of the community and other users of the C1144;
- Minimising impacts on the landscape character of the C1144;
- Upgrading the C1144 to suit construction traffic would create a route that would exceed the requirements of the glen post-construction. This would create an undue maintenance burden and also potentially attract additional traffic to the Glen
- The opportunity to create a suitable junction from the A87;

- The relative structural and alignment suitability of the existing sections of the SAR, which has been designed for and used by heavy forestry traffic, compared with the more constrained alignment and less suitable structural condition of the C1144;
- The unbound surface of the SAR will not require the delivery by the wider public road network of the significant quantity of bituminous material that would be required to upgrade the C1144 if it were to be used for construction traffic; and
- Providing access to the proposed construction main compound and camp area.

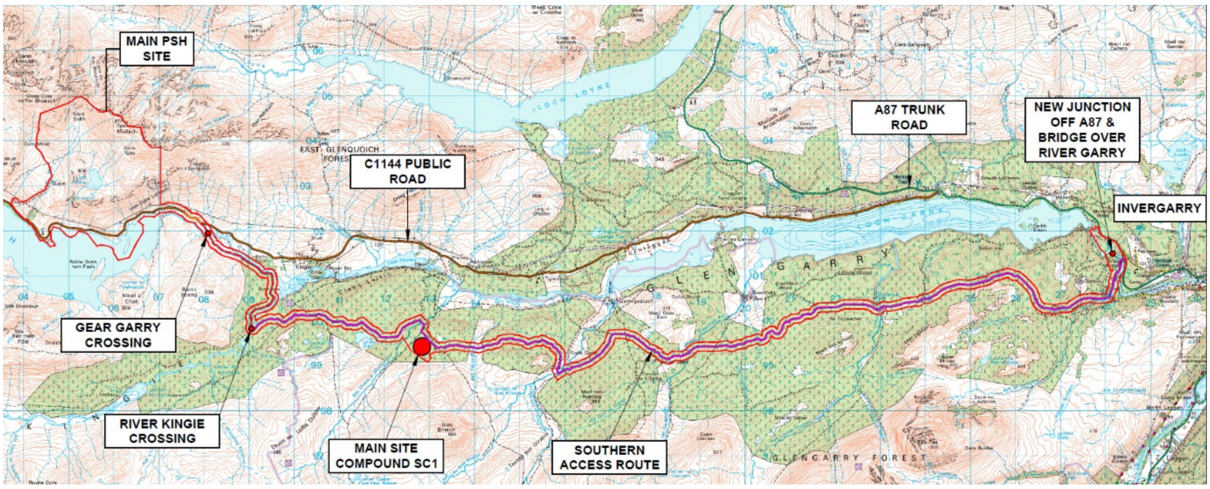

Plate 13 – Access Route Options (Extract from Figure 2.1)

3.6.85 At the east end of the proposed route, the existing White Bridge crosses the River Garry. The Applicant was aware that a proposed new junction off the A87 and River Garry crossing had been consented as part of another PSH project and it could be potentially be shared with the Proposed Development. It is envisaged that this infrastructure will have been constructed in advance of the commencement of the Proposed Development, however is also included within this planning application in the event that the other project does not proceed.

3.6.86 At the western end, the Kingie Bridge would be replaced, and a new bridge would also be constructed over the Gearr Garry. A new section of track approximately 4km in length would be constructed between the two bridges and extended to meet the C1144 to the east of Quoich Dam.

3.6.87 Between the junction of the SAR and C1144 and the main PSH site, the C1144 would be widened to create a dual lane road. This would allow the maintenance of public access whilst also catering for construction traffic. It is envisaged that the C1144 would remain open to the public however under some circumstances there may be a requirement to install traffic control, either during the road widening or delivery of large equipment. This would be contained within the Detailed Construction Traffic Management Plan (CTMP).

3.6.88 The assessment of the two construction access options: i) the C1144; and ii) the SAR, concluded that the SAR should act as the primary construction access. Creating an offline route would reduce the transport impact on the local area, provide a dedicated access route for the project and also allow a main construction compound to be placed remotely from the community of Invergarry, which due to the workforce numbers predicted would be of benefit. Refer to **Figure 2.14 – SAR Proposed Upgrades** for further information.

3.6.89 However it is envisaged that construction vehicles will be required to access the site via the C1144 for the purposes of: i) the ground investigation works; and ii) the enabling works to create the SAR route. Additionally, in the case of emergency and unforeseen circumstances causing the SAR to be unavailable, the C1144 would also be used during the construction period.

3.6.90 During the operational phase, access to the Proposed Development would primarily be taken via the C1144. Daily operational staff, routine maintenance traffic, deliveries and visitors would all use the

C1144, with the SAR only being retained for major maintenance, for instance the removal or delivery of large, heavy equipment which may be an abnormal load and not feasibly taken along the C1144.

Construction Compounds

3.6.91 Projects at the scale of the Proposed Development require significant construction compounds for temporary accommodation, laydown and storage, fabrication, administration and associated services.

3.6.92 With the SAR being selected as the preferred construction access route and available space at the main PSH being relatively limited, potential primary construction compound locations were identified along the route. Secondary compounds would be located within the main PSH site.

3.6.93 These options were discussed with the primary landowner, who has established data on environmental and other constraints along the route. This data was supplemented with additional environmental and topographical survey work by the Applicant, included a peat probing campaign at potential compound locations.

3.6.94 The general approach is that the primary site compound (SC1) would provide a large remote compound that will accommodate the construction workforce whilst also acting as the administrative hub of the project. Staff would be shuttled to and from this compound to their place of work on a daily basis in buses supplied by the contractor.

3.6.95 Staff would work on a 10 day on / 4 day off basis or similar and would remain either within the compound or their place of work for the duration of their stay. When off rota, staff would be shuttled off site to a car parking area near Invergarry by the contractor. No individual staff vehicles would therefore be allowed on the SAR. This would minimise traffic movements around Invergarry, along the SAR and to the main site, thereby improving safety, efficiency and reducing disturbance.

3.6.96 Several site compound locations were identified and reviewed, with the current position of the proposed compound being selected as preferred. This location is a recently replanted Sitka Spruce commercial plantation with thin overlying soil and glacial gravel and rock beneath, which creates favourable construction conditions and minimises ecological impacts.

3.6.97 Other options were discounted on the basis of: i) ancient woodland; ii) presence of protected or rare species; iii) peat depths; iv) other constraints such as existing hydro schemes; v) human impacts; and vi) other projects in development.

3.6.98 The design of site compound SC1 was then developed in further detail. This included: i) a detailed peat probing campaign: ii) earthworks design; iii) layout of accommodation, administration and laydown areas; and iv) visual and noise mitigation measures.

3.6.99 The current SC1 design demonstrates a balance of cut and fill material. Any excess material would be used to create landform screening and covered with the existing topsoil and turf. Existing trees would be retained wherever possible and this would be supplemented with additional planting as screening where required.

3.6.100 The design ran through several iterations to optimise the layout and mitigate impacts. For instance, the accommodation and administration blocks have been moved to the uphill side of the terraces to provide better screening and avoid roof lines protruding above the ridgeline behind.

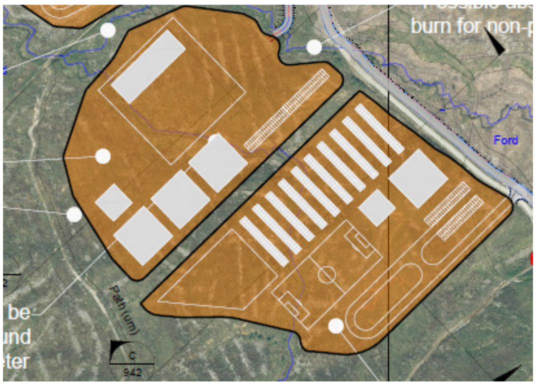

Plate 14 –SC1 design development between June 2024 and December 2024

3.6.101 Site Compound SC2 would be located at the working area adjacent to the proposed powerhouse at the main PSH site. This area would then become the HV switchyard in the latter stages of construction. No overnight accommodation is proposed at this compound.

3.6.102 Site Compound SC3 would be located within the upper reservoir working area. The size and position of this compound would likely develop as the excavation of the borrow pits progressed. Overnight accommodation for 100 staff is proposed at this compound, to allow those workers who are working solely on the upper works to stay in this area and not have to travel back to SC1 whilst on rota.

Permanent and Temporary Site Access Tracks and Paths

3.6.103 Existing access tracks would be used wherever possible on the SAR and main PSH site. As above, the SAR will use existing forest roads, which will be upgraded and extended as required.

3.6.104 On the main PSH site, the existing small access track to the disused quarry would be used for the ground investigation and enabling works and would be replaced with a new track which would be capable of taking the construction and operational traffic.

3.6.105 The track linking the upper and lower works would be a new construction. During the design phase the route was optimised in order to balance the cut and fill volumes and following receipt of the peat probing data, minimise peat volumes. Watercourse crossings have also been minimised where possible.

3.6.106 The design of access tracks follow a 10% maximum gradient. This is deemed an appropriate gradient for construction and operational vehicles to use the tracks safely in most weather conditions. The elevation difference between the two reservoirs governs that the 10% maximum gradient requires to be applied for long sections of the track.

3.6.107 An alternative 12% maximum gradient option was generated however the benefits on material volumes and footprint was modest and not deemed beneficial enough to consider deviating from 10% maximum.

3.6.108 It is envisaged that access to the adjacent Allt Mheil hydro infrastructure may be provided by the Proposed Development access track. This would allow the existing Allt Mheil track to be remediated whilst still providing access if required. The existing track is very steep at around 20% gradient at its steepest and would benefit from improved reinstatement to reduce its visual impact.

3.6.109 The access tracks would be reduced in width following completion of the construction in order to mitigate visual impact, utilise excess peat and turf generated from excavations, promote ecology and reduce the maintenance burden of the project.

3.7 Mass Balance and Borrow Pits

Mass Balance

3.7.1 The planning of the Proposed Development has been developed to create a material balance, with no material proposed to be exported from the site and only the required quantities of rock excavated to construct the scheme. Refer to **Appendix 2.3 – Mass Balance Strategy and Borrow Pit Plan** for further details.

3.7.2 An important aspect of the mass balance will be that the SAR, upper and lower areas of the project aim to achieve mass balance independently, which would avoid significant haul of earthworks materials across the site. However, the design retains the flexibility to be able to move some volumes of material should they be required.

3.7.3 As described in this chapter, different construction types, designs and methodologies have been considered and assessed to then inform the preferred solutions for the Proposed Development. Mass balance is a key consideration in the development and assessment of options, as generally the most efficient generation and use of excavated materials is key to the successful delivery of the project.

Construction Borrow Pits (Descriptions and Evolution of their Selection)

3.7.4 A number of potential borrow pit locations and configurations were identified and assessed through the design process.

3.7.5 On the SAR, the general approach would be to extend existing borrow pits where possible. This has a number of benefits, including certainty that the material at these locations is suitable for its intended purpose, which is the upgrade and extension of existing forest roads and the construction of compound SC1.

3.7.6 At the PSH lower works, the powerhouse surface and shaft excavations and tunnel arisings would generate sufficient quantities of rock to infill and raise the quarry area, build the access track to the upper reservoir, landscape mitigation measures and produce concrete aggregate. Any excess material would be used in the construction of the upper dams.

3.7.7 Separate borrow pits were initially proposed at the lower works, however the development of the design showed that a lower borrow pit would not be required and it has therefore been removed.

3.7.8 At the upper works, three borrow pits are proposed. Each of these borrow pits would be located within the upper reservoir inundation i.e. below the maximum operating level.

3.7.9 Initially, borrow pits with steeper back faces were proposed, with floor levels around the minimum operating water level. Geotechnical engineering review identified that the borrow pit design could be improved by reducing the steepness of the back faces and dropping the floor level. The result was an improvement in the stability of the borrow pits, reduced visual impact and easier construction, all achieved with the same gross borrow pit volumes.

3.8 Sustainability Considerations

3.8.1 The iterative design process has sought to reduce the Proposed Development footprint without compromising safety and the long-term security of the infrastructure. This will result in a reduction of raw materials required to construct the Proposed Development, reducing GHG emissions associated with the raw extraction and processing of materials, as well as transport emissions associated with material import. Additionally, there is a reduced area requiring excavation and less waste generated, reducing GHG emissions associated with these activities and waste transportation. These principles will be adopted during the detailed design of the Proposed Development as the individual elements are further refined.

3.8.2 During the design process, due regard has been given to Hydropower Sustainability Guidelines (IHA, 2020). This document sets out international good practice throughout the lifecycle stages of a hydropower project and includes a section on Climate Change Mitigation and Resilience. It includes a series of design and construction measures to reduce GHG emissions and improve the climate resilience.

3.9 Conclusion

3.9.1 A nationwide screening exercise to identify PSH sites was undertaken by the Applicant and their Agents. The Proposed Development site was identified as having strong potential as a PSH scheme for the following reasons:

- Suitable topography and geology to be able to create substantial upper and lower reservoirs and a waterway system to provide meaningful LDES at scale;
- Practicable access to the electricity transmission network;
- Practicable access to the site;
- A footprint that can be configured to minimise the effects on the natural environment from construction and operation of the scheme.

3.9.2 The project team has considered the options for the scheme arrangement and has developed the design to minimise its footprint on local ecology and maximise the capacity and storage potential of the site.

3.9.3 The main refinements of the design since Scoping stage have been to:

- Reduce generation capacity from a maximum of 2,000MW to a maximum of 1,800MW, thereby reducing the scale of the works required;
- Refine the upper reservoir dam arrangements;
- Refine the location of the primary site compound SC1;
- Increase the size of the HV switchyard to accommodate the required equipment;
- Develop the powerhouse design concept;
- Develop a significant local biodiversity enhancement and management programme to ensure biodiversity net gain in the local area; and
- Utilise the majority of earthworks arisings within the dam structures and maintain a balance of materials within both the upper and lower parts of the site.

3.9.4 The extensive development process, as set out in this chapter, has demonstrated that the Proposed Development is an excellent PSH site. In consultation with stakeholders the design team has refined the arrangement through the design development process to finalise the project detail that forms the final planning application.